Standard Tables and Equations in Radio-Telegraphy

BY

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INTRODUCTION

The author has had in view the object of extending the scope and number of equations and tables given in the "Year Book of Wireless Telegraphy," and of adding numerous tables and equations facilitating calculations occurring in the subject of wireless telegraphy.

No such complete book of tables and equations exists, for the specific use of wireless engineers and others, under a single cover, which is the author's excuse for putting these into the present form.

A few worked examples are shown of some of the more difficult expressions, notes to this effect being made in the margin opposite the equation chosen and worked as an example.

A special point has been made of giving in every paragraph dealing with an equation a list of the meanings and units used in that equation. This has enabled the author to maintain the identity of the symbols and their meanings as used in certain equations by different authors, thus facilitating back reference to the originals when required.

For instance, one comes across "B" used as a correcting function in aerial capacity formulæ (par. 5) and as another correcting function having a totally different significance in inductance formulæ (par. 7). These differences are clearly brought out by the explicit lists of symbols given. The major portion of the tables given in the 1917 "Year Book of Wireless Telegraphy" are included in the present book of tables, together with numerous others abstracted intact from other sources or modified by the author to suit the particular requirements of the present work; whilst several others are computed by the author himself specially for these tables.

The author is indebted to Messrs. V. A. Smart and R. Price-Smith for their valuable contributions of tables of a mechanical engineering nature, for notes on arithmetical processes, and for

useful information on aerial stays and insulators, and to The London Electric Wire Co. for permission to publish such of their tables and formulæ as were needed.

The author hopes that wireless engineers, designers, students and others will find these tables and equations useful in the course of their work.

B. HOYLE.

January, 1919.

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USEFUL FORMULÆ AND EQUATIONS. SECTION I

(The names of the Authors are given in square brackets.)

Subject.	Formula.			Notes.
1. Practical Electromagnetic **Units** and **Symbols** in use.	Current, I	Ampère	10^{-1}	The numbers give the values of the Practical Units in C.G.S. Electromagnetic Units.
	Electromotive Force Voltage Pressure Difference of Potential	E or V, Volt	10^{8}	
	Quantity of Electricity, Q	Coulomb	10^{-1}	Small letters are used when the quantities are variable. $KE = Q$
	Capacity, K or C	Farad	10^{-9}	
		Microfarad	10^{-15}	
	Inductance, L	Henry	10^{9}	The C.G.S. Unit of Inductance is also used in Wireless = 1 cm.
		Microhenry	10^{3}	
	Resistance, R	Ohm	10^{9}	
2. **Work, Energy** and **Power**	Work or Energy, W	Joule	10^{7}	1 Joule = 1 watt for 1 second.
		Foot-pound	$1{\cdot}356 \times 10^{7}$	Work done in raising one pound one foot = 1 foot-pound.
		Kilogrammeter	$9{\cdot}8 \times 10^{7}$	
		Kilowatt-hour	$3{\cdot}600 \times 10^{10}$	
	Power or Activity, P	Watt	10^{7}	1 watt = 1 amp. × 1 volt per second = 10^7 ergs, an erg being the work done in producing an acceleration of one centimetre per second per second in the motion of a mass of one gram.
		Kilowatt	10^{10}	
		Horse Power	746×10^{7}	
	or 33,000 ft.-lbs. per min. or 550 ft.-lbs. per sec.		[Watt.]	

SUBJECT.	FORMULA.	NOTES.
3. Relation between **Work** and **Heat.**	The Heat required to raise the temperature of one pound of water 1° F. is called Joule's Equivalent, $J = 776$ ft.-lbs. If the heat unit be 1 gram-degree Centigrade, Joule's Equivalent, $J = 4 \cdot 2 \times 10^7$. [Joule.]	
	Heat produced by current in wire = Amps × Volts/4·2. [Joule.]	Gram-degrees Centigrade per second.
4. **Frequency, Wave-length, and Velocity of Waves.**	The velocity of Light and of Free Electromagnetic Waves $v = 186{,}000$ miles per second $= 3 \times 10^8$ metres per second [Fizeau.] [Maxwell.]	
	λ = wave-length, from crest to crest or positive to next positive. n = frequency = cycles per second. T = duration of one complete cycle = period. $T = 1/n$; $\lambda = v/n$.	Symbol — also used for frequency. *E.g.*, the period of a wave of frequency 500,000 is 1/500,000 sec., and since $600 = 3 \times 10^8/5 \times 10^5$ a 600 metre wave has a frequency of 500,000.
C.G.S. or **Absolute Units** .	(See Synopsis of Units, etc., Table 30.)	
5. **Capacities** . . .	(*a*) Sphere of radius = r cms., in open space $K = r/9 \times 10^5$ microfarads	
Capacity, condenser . .	(*b*) Parallel Plate Condenser:— A = total area of working sides of plates connected to one terminal, in sq. cms. d = distance between + and — plates in cms.	See table of Sp. Ind. Capacities, Table 21 (page 57).

k = specific inductive capacity of dielectric

$$K = \frac{Ak}{11{\cdot}31 \times 10^6 \times d} \quad . \; . \; . \; . \text{ mfd.}$$

The Sp. Ind. Cap. of Air = 1.
See Example 1 (page 70).

(*c*) Parallel Plate Condenser (Composite Dielectric) :—

Let dielectric be part air and part material of S.I.C. = k.

Let t = thickness of slab of insulation in cms.

d being as before the distance apart of + and − plates in cms.

Then $(d - t)$ is the air thickness and $\frac{t}{k}$ is the equivalent air thickness of the insulating slab

so that $\left\{(d - t) + \frac{t}{k}\right\}$ = total equivalent air thickness

whence $K = \dfrac{A}{11{\cdot}31 \times 10^6 \left\{(d - t) + \frac{t}{k}\right\}}$ mfds.

Example 21 (page 94).

(*d*) Parallel Circular Plates :—

Let r = radius of plate in cms.
d = distance apart, in cms.
t = thickness of metal plate.

Then capacity

$$K = \left[\frac{r^2}{4d} + \frac{r}{4\pi}\left(\log_e \frac{16\pi r(d - t)}{d^2} - 1 - \frac{t}{d}\log_e \frac{d + t}{t}\right)\right]\frac{k}{9 \times 10^5} \text{ mfds.}$$

Example 22 (page 94).

or when t is small compared with d

$$K = \frac{r^2 k}{4d \times 9 \times 10^5} \text{ mfds., which is}$$

$$\text{equivalent to } \frac{Ak}{4\pi d \times 9 \times 10^5} \text{ mfds}$$

$$\text{or } \frac{Ak}{11{\cdot}31 \times 10^6 d} \text{ mfds. already given in (}b\text{).}$$

Subject.	Formula.	Notes.
Concentric Cylinders	(*e*) Concentric Cylinders :— r_1 = outer radius of inner electrode. r_2 = inner radius of outer electrode. l = length in cms. k = sp. inductive capacity. K = capacity in microfarads. $K = kl \div \left(4{\cdot}144 \times 10^6 \log_{10} \frac{r_2}{r_1}\right)$ mfd.	Capacities in series. $\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} +$ etc., where K_1, K_2, K_3, etc., are the capacities of units in series. In parallel $K = K_1 + K_2 + K_3 +$ etc.
Capacity, Horizontal Aerial.	(*f*) Horizontal Wire above Earth :— l = length in cms. d = diameter in cms. h = height above earth in cms. K = Capacity in microfarads. $K = l \div \left(4{\cdot}144 \times 10^6 \log_{10} \frac{4h}{d}\right)$ mfd.	
	(*g*) Multiple Wire Horizontal Aerial :— n = number of wires in span. l = length of span in cms. d = distance apart of wires in span in cms. r = radius of wire in cms. B = function depending on N E = function of the ratio $\frac{l}{2h}$ K' = capacity in micro-microfarads per foot of span.	(Table 8, page 40.) (Table 7.) This takes account of the effect of proximity of the earth, on the resulting capacity.

	$K' = \dfrac{17n}{n\left(\log_e \frac{l}{d} - 0{\cdot}31 - \frac{E}{2}\right) + \log_e \frac{d}{r} - \mathrm{B}}$ [Howe.]	Example 2 (page 70).
6. Capacity, Measurement of .	To measure H.F. capacity :— (i.) Put in series with known inductance and measure wave-length given out by current when oscillating, or, (ii.) Put it in series with an oscillating circuit having known capacity and measure the change of wave-length. λ = wave-length in meters. K = capacities measured in mfds. L = inductances measured in cms. In (i.) $K_1 = \dfrac{\lambda^2}{3555\,L}$ mfds. In (ii.) $K_1 = K \cdot \dfrac{\lambda_1^2 - \lambda_1^2}{\lambda_1^2}$ mfds.	
7. Inductance . . .	a = radius of centre of conductors in cms. b = overall breadth of coil in cms. l = length of wire in cms. r = radius of wire in cms. n = total number of turns. N = turns per cm. d = diam. of bare conductor. D = distance apart of centres of conductors. L = inductance in cms.	This includes the insulation.
Inductance, Straight Wire ..	$L = 2l\left(\log_e\left(\frac{2l}{r}\right) - 1\right)$ cms. [Neumann.]	

Subject.	Formula.	Notes.
Inductance, Square	$L = 2l\left(\log_e\left(\frac{l}{r}\right) - 1{\cdot}91\right)$ cms. [Kirchoff.]	Where l = total length of wire in square in cms.
Inductance, Circle	$L = 12{\cdot}57a\left[\left(1+\frac{r^2}{4a^2}\right)\log_e\left(\frac{8a}{r}\right) - 2\right]$ cms. [Rosa.] or approximately $L = 12{\cdot}57a\left[\log_e\left(\frac{8a}{r}\right) - 2\right]$ cms. $= 12{\cdot}57a\left[2{\cdot}3026\log_{10}\left(\frac{8a}{r}\right) - 2\right]$ cms. [Kirchoff.]	
Inductance, Solenoid	$L = 4\pi^2a^2N^2b$ $= 39{\cdot}49a^2N^2b$ cms. for long solenoids only. $L = 4\pi^2a^2\frac{N^2}{l}\left(1 - \frac{8a}{3\pi l} + \frac{a^2}{2l^2} - \frac{a^4}{4l^4} + \frac{5a^6}{16l^6} \mp \text{etc.}\right)$ cms. [Webster and Russell.]	N = turns per cm. (Example 20, page 94). Approximate formula only.
Inductance formulæ for solenoids of all dimensions.	No single formula holds over large ratios of $\frac{a}{b}$. Two formulæ, however, cover a wide range, sufficient for all practical purposes. $L_s = an^2Q$ cms. [Coffin, Lorenz.] $L_s = 4\pi an^2X$ cms. [Rayleigh.]	See Table 9 for values of Q for various ratios of $\frac{2a}{b}$ (page 41). See Table 10 for values of X for various ratios of $\frac{a}{b}$ (page 42).

N.B.—Both these formulæ require corrections applying for numbers of turns and insulation thickness.

Example 3 (page 70).

In both cases

True inductance $L = L_s - \Delta L$

where $\Delta L = 4\pi a n (A + B)$ cms.

See Tables 11 and 12 for values of A and B (page 43).

Inductance of "Pancake" coils or toroidal coils.

c = radial depth of spiral.

= difference of inner and outer radii in cms.

$y_1 y_2$ are functions of the ratios $\frac{b}{c}$ or $\frac{c}{b}$.

See Table 13 for values of $y_1 y_2$ and E_1 (page 44).

The results given by this equation are less accurate as the value of $\frac{c}{a}$ increases.

$$Lu = 4\pi a n^2 \left[\left(1 + \frac{3b^2 + c^2}{96a^2} \right) \log_e \frac{8a}{\sqrt{b^2 - c^2}} - y_1 + \frac{b^2}{16a^2} y_2 \right] \text{cms.}$$

[Stefan.]

Corrections must be applied by the following formula :

Example 4 (page 72).

True $L = Lu + \Delta' L$ cms.

$$\text{where } \Delta' L = 4\pi a n \left[\log_e \frac{D}{d} + 0{\cdot}13806 + E_1 \right] \text{cms.}$$

Stefan's equation is not very accurate when $\frac{c}{b}$ or $\frac{b}{c}$ is less than 0·1.

Inductances in series and parallel.

Inductance of two or more coils, in series, with no mutual inductance.

$$L = L_1 + L_2 + \quad . \quad . \quad .$$

Inductance of two coils, in parallel, with no mutual inductance.

$$L = \frac{L_1 L_2}{L_1 + L_2}$$

SUBJECT.	FORMULA.	NOTES.
	Inductance of two coils, in series, with mutual inductance $M_{1.2}$, $L = L_1 + L_2 \pm 2M_{1.2}$.	
Mutual Inductance	Let N_1N_2 = total number of turns on coils (i.) and (ii.). Mo = the mutual inductance of equivalent circles at the centres of the coils. Then the mutual inductance $M = n_1n_2Mo.$ where $Mo = 16\pi^2 \sqrt{Aa} \cdot i^{\frac{3}{2}} (1 + e)$ cms., A and a being the radii of the two coils in cms., d the axial distance between centres of coils, cms., $Mo = \sqrt{Aa} \cdot \gamma$ cms., γ being a function of the ratio $\frac{r_2}{r_1}$ the least and greatest distance between points on the two circles. [r_2 is the distance between similar ends of parallel diameters of the two equivalent circles. r_1 is the distance between opposite ends of parallel diameters.] Thus mutual inductance $M = N_1N_2 \sqrt{Aa} \cdot \gamma$ cms. NOTE.—Where the coils are not very far apart, each coil should be represented by two imaginary equivalent circles, instead of one, their distance apart being $2g$ where $g = 0{\cdot}2887b$, b being the breadth of the coil in question.	See Table 14 (page 45). NOTE.—$\frac{r_2}{r_1}$ may be calculated from the following, if direct graphical measurement is not convenient: $\frac{r_2}{r_1} = \frac{\sqrt{(A - a) + d^2}}{\sqrt{(A + a) + d^2}}.$ Example 5 (page 72).

	Let the four equivalent circles be P and Q for one coil and R and S for the other. Then work out $Mo = \sqrt{Aa} \,.\, \gamma$ cms. as above, for P and R P and S Q and R Q and S, and take the mean. Then $M = Mo$ (mean) $\times N_1 N_2$ cms.	
Mutual inductance, measurement.	Connect the two coils in series, and measure the total inductance of the system. Call this L_A say. $L_A = L_1 + L_2 + 2M$ if connections are such that the fluxes are acting together. Reverse the connections and measure the new inductance. Call this L_B. $L_B = L_1 + L_2 - 2M$ if the connections are now such that the fluxes are in opposition. Whence $M = \dfrac{L_A - L_B}{4}$.	Reference : — For a complete account of all the formulæ for calculation of Self- and Mutual Inductance, see "Bulletin of Bureau of Standards," Vol. 8, No. 1, Washington, D.C.
9. **Coupling, Coefficient of**	Let λ_1 = longer wave of a coupled system. λ_2 = shorter wave of a coupled system. K = coefficient of coupling. $K = \dfrac{\lambda_1^2 - \lambda_2^2}{\lambda_1^2 + \lambda_2^2}$. [Zenneck.]	See Table 20 for values of K for various ratios of wave-length and frequency (page 55). See Example 6 (page 73).

SUBJECT.	FORMULA.	NOTES.
	This is very approximate when the two peaks occur close together as they do when the circuits are very loosely coupled. The coefficient of coupling is more accurately given by $K = \sqrt{\frac{M_{12} \cdot M_{21}}{L_1 \cdot L_2}}$ or $\frac{M_{12}}{\sqrt{L_1 \cdot L_2}}$ where M_{12} = effective mutual inductance of 1 on 2. M_{21} = effective mutual inductance of 2 on 1. L_1 = effective self-inductance of 1. L_2 = effective self-inductance of 2. M_{12} is taken as being equal to M_{21}, whence the simpler alternative.	
	$T_1 = T\sqrt{1+k}$ $T_2 = T\sqrt{1-k}$ $n_1 = \frac{n}{\sqrt{1+k}}$ $n_2 = \frac{n}{\sqrt{1-k}}$ $\lambda_1 = \lambda\sqrt{1+k}$ $\lambda_2 = \lambda\sqrt{1-k}$ and $k = \frac{\lambda_1^2 - \lambda_2^2}{\lambda_1^2 + \lambda_2^2}$	Where T, n, λ are the time period, frequency and wave-length of each circuit separately, and T_1, T_2, n_1, n_2, and λ_1, λ_2 are the corresponding values of the two resultant waves produced by coupling.
10. Aerial Inductance, Capacity, and Resistance.	L_a = antenna inductance, in henries. K_a = antenna capacity, in farads.	

R_a = antenna resistance, in ohms.
R' = series resistance added at base of aerial.
δ = aerial log. dec. per period.
δ' = added log. dec. due to R'.
λ = wave-length in metres.
n = frequency of oscillations.
E = voltage, effective.

$$\text{Then } L_a = \frac{R'}{6 \times 10^8 \delta'} \cdot \lambda \text{ hys.}$$

$$K_a = \frac{\delta'}{6\pi^2 10^8 R'} \cdot \lambda \text{ fds.}$$

$$R_a = \frac{\delta}{\pi} \sqrt{\frac{L_a}{K_a}} \text{ eff. ohms.}$$

$$\delta' = \frac{R'}{2nL_a} \text{ per period.}$$

Power absorbed by aerial $= R_a I_a^2$. — I_a being the R.M.S. current measured at the base of the aerial.

$$I_a = 2\pi n K_a E \text{ amps.}$$

Radiation resistance and decrement of aerials.

h = aerial height in metres.
λ = aerial wave-length in metres.
a = aerial "form factor." — See Example 11 for explanation of a (page 77).
R = radiation resistance in ohms.

$$R = a^2 \left(160\pi^2 \left(\frac{h}{\lambda}\right)^2\right) \text{ ohms.}$$

See Table 30 for $\left(160\pi^2 \left(\frac{h}{\lambda}\right)^2\right)$ (page 67).

$$\text{and } \delta = \frac{R}{4nL} \text{ per semi period.}$$

n = frequency.
L = inductance in henries.

SUBJECT.	FORMULA.	NOTES.
Aerial Form Factor .	a = aerial form factor. h = height of aerial. L = length of horizontal part for Γ aerials. = half total length for flat top T aerials. $a = 0{\cdot}637\left(1 + \frac{L}{h}\right) \sin\left(\frac{h}{h+L}\right) 90^\circ.$	NOTE.—h and L are to be both in the same measure, say both feet or both metres, etc. See Table 33 (page 69).
Aerial Radiation . .	w = watts radiated. h = height of aerial in metres. λ = wave-length of aerial in metres. a = form factor (Table 33). I = R.M.S. current in aerial measured at the base. $w = 1{,}578 \frac{h^2 a^2 I^2}{\lambda^2}$ watts.	
11. Resistance at High Frequencies.	*Straight Copper Wire* of radius = r cms. R_o = resistance to direct current (see Tables 15). R_n = resistance at frequency n. $R_n = R_o\left(1 + \frac{1{\cdot}121}{10^5} n^2 r^4 - \frac{1{\cdot}007}{10^{10}} n^4 r^8\right)$ [From Rayleigh's formula.] Another formula— $R_n = R_o r \sqrt{0{\cdot}0058 n}$ [From Rayleigh's formula.] Table 18 gives values of R_n for various sizes of wires and various frequencies n.	Note the resistance of manganin wire of about 0·8 mm. diameter is practically the same for C.C. as for wireless frequencies. When frequency very high. Example 25 (page 98).
Resistance for continuous current.	Let R = resistance in ohms. L = length of conductor in cms.	

A = cross-section of conductor in sq. cms. ρ = specific resistance in ohms per cm. cube. Then $R = \rho \frac{L}{A}$.	$\rho = 1{\cdot}724 \times 10^{-6}$ for soft copper and $1{\cdot}760 \times 10^{-6}$ for hard copper at 68° F.
$R_t = R_o (1 + \alpha_t)$. where R_t = resistance in ohms at t° C. R_o = resistance in ohms at o° C. α = temperature coefficient per degree C.	See Table 22 for ρ and α (page 58).
$H = 0{\cdot}24\, I^2RT$. where H = calories. T = time in seconds. I = current in ampères.	
Let I_x = current at depth x cms. I_{max} = "skin" or surface current. f = frequency in cycles per sec. a = radius of conductor in cms.	See Example 26 (page 98).
Then $\frac{I_{max}}{I_x} = \epsilon^{0{\cdot}15708x\sqrt{f}}$	For copper wires where $\mu = 1{\cdot}0$ $\sigma = 1{,}600$.
also $\frac{I_{max}}{I_{RMS}} = \sqrt{0{\cdot}31416a\sqrt{f}}$.	$\frac{I_{max}}{I_x} = \epsilon\left(\frac{2\pi\mu p}{\sigma}\right)^{\frac{1}{2}}x$ for other materials.
So that current at a depth x cms. shall be $\frac{1}{100}$th of the surface value I_{max}, $x = \frac{29{\cdot}30}{\sqrt{f}}$ cms.	See Notes and Example 26 (page 98).

SUBJECT.	FORMULA.	NOTES.
12. Logarithmic Decrement .	Resistance decrement. R' = high frequency resistance in ohms. n = frequency of oscillations. L = inductance in henries. δ = log. dec. per semi-period. $\delta = \frac{R'}{4nL}$.	See Example 11 and Table 18 (pages 51 and 77 respectively).
Damping, Logarithmic decrement.	If I_1, I_2, I_3, etc., be successive positive maximum values of current $I_1/I_2 = I_2/I_3 = \ldots = \epsilon^{dT}$ and $I_2/I_1 = I_3/I_2 = \ldots = \epsilon^{-dT} = \epsilon^{-\delta}$ $dT = \log_e (I_1/I_2) = \delta$, and $d = n\delta$ hence (see above) $i = I\epsilon^{-n\delta t} \sin 2\pi nt$ is the equation to an oscillatory current having log. dec. = δ per cycle Also if I_m be the mth maximum $I_m/I_1 = \epsilon^{-(m-1)\delta}$ since I_m is I_1 multiplied by $(m - 1)$ factors each = $\epsilon^{-\delta}$	T = period. δ = log. Decrement per whole period. Also, $\delta = R/2nL$.
Wave Train, Useful length of	Thus when the energy has fallen to 1/100 of that of first maximum and the current therefore to 1/10 $m = \frac{2{\cdot}3026 + \delta}{\delta}$ = a certain number of cycles.	This gives the useful length of a wave train when the decrement is known.

In a circuit containing a gaseous section or spark, the resistance in general increases with the decrease of current; hence the decrement increases as the current dies out and the law is not logarithmic.

From experimental determinations it is known that the decrement of a spark circuit is approximately a straight line and not a logarithmic curve—*i.e.*:

$$I_1 - I_2 = I_2 - I_3 = \text{constant} = D.$$

[Zenneck.]

Hence
$$I_n = I_1 - (n-1)D$$
and the spark is extinguished and the current stops when
$$(n-1)\,D = I_1 \text{ or } > I_1.$$

If a wavemeter—*i.e.*, a circuit having a standardised variable capacity, an inductance, and an indicator of current (usually a hot wire ammeter) in series—be placed so that current is induced in it by the action of another oscillating circuit, the current so induced varies with the nearness of the natural frequency of the wavemeter circuit to that of the inducing current. The curve obtained by plotting values of the square of the current in the wavemeter (I_2^2) against corresponding values of natural frequency of the wavemeter circuit (n_2) is called a resonance curve. When the frequency of the wavemeter is equal to that of any wave existing in the exciting circuit the current in the wavemeter runs up to a maximum and there is a peak on the curve. From the form and position of this peak or peaks the character of the exciting oscillation can be deduced. For instance, the frequency and damping of the exciting waves can be determined. [Bjerknes.]	Wavemeter Indicator. A telephone is often used to find wave-lengths or frequencies only; the reading of the wavemeter for maximum loudness being the wave-length of the exciting oscillation.

Subject.	Formula.	Notes.
...ination of log. dec. tuning curve data.	The accurate formula for log. dec. δ per half period, where— $\frac{\lambda_1}{\lambda_2}$ is the ratio of wave-lengths near the tune point (always taken less than unity) of which one wave-length is the resonant wave-length. $\frac{I_o}{I_1}$ is the ratio of current obtained at resonant wave-length (I_o) to that obtained at the adjacent wave-length (I_1) is given by the formula— $$\delta = \frac{\pi}{2}\left(1 - \frac{\lambda_1^2}{\lambda_2^2}\right)\left(\frac{1}{\sqrt{\left(\frac{I_o^2}{I_1^2} - 1\right)}}\right)$$ [Bjerknes.] More approximately this is— $$\delta = \pi\left(1 - \frac{\lambda_1}{\lambda_2}\right)\left(\frac{1}{\sqrt{\left(\frac{I_o^2}{I_1^2} - 1\right)}}\right).$$ N.B.—δ is given as the decrement per half period. δ includes the decrement of the testing circuit δ_2, as well as the value of δ_1, the true decrement one wishes to determine. Generally δ_2 is small, and approximately calculable from $\delta_2 = \frac{R'}{4nL}$. It is unnecessary to plot the whole curve; for, by taking appropriate values of the ratios of λ and I the value of δ can be read off from the Table 19. In the above $\delta = \delta_1 + \delta_2$.	Table 19 gives values of δ calculated from this equation (page 53).

Energy in a charged condenser

W = watt-seconds or joules.
K = capacity in farads.
E = voltage of condenser charge.

$$W = \tfrac{1}{2}QE = \tfrac{1}{2}KE^2 \text{ joules (watt-seconds).}$$

[Kelvin.]

If K is in microfarads and E in volts,

$$W = \frac{1}{2 \cdot 10^6} KE^2 \ldots\ldots \text{ joules (watt-seconds)}$$

$$= \frac{1}{72 \times 10^{11}} KE^2 \ldots\ldots \text{ kilowatt-hours.}$$

Energy in Inductance Carrying Current.

If L in henries and I in ampères,

$$W = \tfrac{1}{2}LI^2 \ldots\ldots \text{ joules (watt-seconds).}$$

$$W = \frac{1}{72 \times 10^5} LI^2 \ldots\ldots \text{ kilowatt-hours.}$$

Frequency (per second) = (revs. per min. × Number of Poles) ÷ 120.

In the Goldschmidt H.F. alternator the frequency is raised by addition of resonating circuits to stator and rotor—*e.g.*, if frequency as ordinary alternator be 10,000; frequencies of 20,000 or 30,000, or 40,000, etc., can be obtained in aerial circuit according to the number of intermediate circuits used.

The curve representing the equation

$$y = A \sin x$$

is a simple sine curve, where A is the maximum value of y, or amplitude.

SUBJECT.	FORMULA.	NOTES.
	Usually the curve of an alternator is not a simple sine curve but represents $y = A_1 \sin x + A_2 \sin 2x + A_3 \sin 3x + \ldots$ these terms represent harmonics, where A_1, A_2, etc., are their amplitudes.	
16. Simple Harmonic Motion.	The equation $y = \sin 2\pi nt$ represents a simple periodic motion of frequency n.	t = time.
17. Hot Wire Ammeters .	High frequency alternating and interrupted currents are usually measured by means of hot wire ammeters. The quantity measured is not the actual current at any instant, but the effective value of the current over a number of cycles or wave trains.	
R.M.S. Ampères. . .	The value indicated by a hot wire instrument is the root of the mean square of the current = R.M.S. ampères.	For sine waves the R.M.S. amps. = $\frac{1}{\sqrt{2}}$ (maximum instantaneous current) = 0·707 (I_m).
18. Impedance . . .	In an alternating current circuit the ratio volts ampères is a constant and is called the Impedance. Impedance = Volts Ampères	R.M.S. volts and ampères are applicable here.

	In a circuit having inductance, capacity and resistance in series, where $p = 2\pi n = 6{\cdot}28n$, $$\text{Imp} = Z = \sqrt{\left(pL - \frac{1}{pK}\right)^2 + R^2}$$ [Kelvin.] R = Resistance ; $\left(pL - \frac{1}{pK}\right)$ = Reactance.	If the units are henries, farads and ohms the impedance is equivalent to ohms.
	If there is no capacity in series—*i.e.*, a conducting circuit throughout, $$\text{Imp} = \sqrt{p^2L^2 + R^2}$$	See also 20.
. Exponential or Logarithmic Function.	The equation $$y = \epsilon^x$$ or, $\log_\epsilon y = x$ represents a law of variation of common occurrence in nature. For instance, in the form $$y = \epsilon^{-at}$$ where a is a constant property chosen, the equation represents : (1) The charge y at any time t in a condenser which is leaking through a resistance ; (2) The curve through the successively decreasing maxima of a damped oscillation in a circuit of constant resistance. The equation $$y = \epsilon^{-ax} \sin bx$$ represents a damped train of waves or oscillation.	$\epsilon = 2{\cdot}71828$ and is the base of Napierian logarithms.
Charging voltage for a condenser.	V_o = pressure in volts. R_o = circuit resistance in ohms. K = capacity in farads. t = time in seconds.	

Subject.	Formula.	Notes.
	Then instantaneous voltage $V = V_0\left(1 - \epsilon^{-\frac{1}{R_0 K}t}\right)$.	
20. Oscillatory Current . .	The equation giving the current at any moment in a damped oscillation is $i = I\epsilon^{-at} \sin 2\pi nt$. [Kelvin.]	
Frequency . . .	The frequency of a free oscillation in a circuit not coupled to any other is $n = \sqrt{(4LK - R^2K^2)}/4\pi LK$	Note.—For oscillations to be possible R must be less than $\sqrt{4L/K}$.
	Or if R^2K^2 is small and if K and L are in farads and henries $n = 1/2\pi\sqrt{KL}$	n is in complete cycles per second.
	$\lambda = 6\pi 10^8 \sqrt{KL}$	$\lambda = v/n = 1{,}885\ \sqrt{KL}$ metres.
	or $n = 159200/\sqrt{KL}$ if K is in microfarads, L in microhenries,	
	or $n = \dfrac{5 \times 10^6}{\sqrt{L \text{ cms. } K \text{ mfds.}}}$	More accurately 5·033.
	$\lambda = 60\ \sqrt{L \text{ cms. } K \text{ mfds.}}$	More accurately 59·6.
Angle of Lag . . .	If the current in an alternating (or oscillating) circuit is always behind, or before, the voltage in arriving at corresponding values, the current is said to lag, or lead, and there is a difference of phase between current and voltage. The amount of lag or lead is measured by the difference in the phase angles of the harmonic motions representing current and voltage; this angle ϕ is called the angle of lag, or lead,	

	$\tan\phi$ = Reactance/Resistance $= \left(pL - \frac{1}{pK}\right)/R.$	$p = 2\pi n. \quad n = \frac{v}{\lambda}$ where $v = 3 \times 10^8$ and λ is in metres.
r Factor . . .	The power taken in, or given out and dissipated, by a circuit in which the phase difference is ϕ is $P = (IE)\cos\phi$ $\cos\phi = \frac{\text{Resistance}}{\text{Impedance}} = \frac{R}{\sqrt{\left(pL - \frac{1}{pK}\right)^2 + R^2}} = \frac{\delta}{\pi}$ Hence the power taken by an oscillating circuit $P = \frac{\delta}{\pi}(IE).$	I and E are effective or hot-wire instrument values, δ = log. dec. Hence, when δ small $\cos\phi$ is small and power is small, and when δ large, other things being equal, the power taken is large. N.B.—In this formula δ is the log. dec. per period.
rona Voltage . .	Let h = barometric height in inches. T = absolute temperature in degrees F. ($T = 459{\cdot}2 + t$) where t is the thermometer reading in degrees F.	
	r' = effective radius of conductor.	See Table 31 (page 68).
	r = radius of conductor in inches.	Wire Tables 15 (pages 46 to 51).
	l = distance apart of conductors in inches. E_{max} = voltage at which corona effect appears.	
	$E_{max} = 36{,}800 \frac{hr'}{T} \log_{10}\left(\frac{l}{r}\right) \times Bd \times 10^{10}$ volts.	See Table 31 for $Bd \times 10^{10}$ (page 68).
	For $t = 60^\circ$ F. and $h = 30{\cdot}00$ inches. $E_{max} = 2{,}125{\cdot}5r' \log_{10}\left(\frac{l}{r}\right) \times Bd \times 10^{10}$ volts.	See Example 17 (page 85).
nsmission . . .	I_1 = sending antenna current. I_2 = receiving antenna current. h_1 = height of sending antenna. All in kilometres. h_2 = height of receiving antenna. ,, ,, λ = wave-length. ,, ,,	Receiving antenna supposed to have resistance about 25 ohms; which is common in practice. A current of 40 microampères in the receiving antenna is necessary

SUBJECT.	FORMULA.	NOTES.
	d = distance between stations. All in kilometres. α = dissipation constant = 0·0015 in daylight over sea. $$I_2 = 4 \cdot 25 I_1 \frac{h_1 h_2}{\lambda d} \cdot \epsilon^{-\alpha d / \sqrt{\lambda}}.$$ [Austin.] N.B.—α is sometimes as great as 0·00195.	for good reception with ordinary detectors, but with audion amplifiers and similar arrangements much less is required. Example 7 (page 74).
22. Efficiency of Transmitting Aerial-Earth Circuit.	To find the efficiency of a transmitting antenna set up a small antenna at a few wave-lengths distant from the station. Put sensitive hot-wire ammeter in this antenna. Measure the current i_1 received when the current I_1 is in the station antenna. Lower the station antenna about 10 per cent. of its height. Measure i_2 and I_2. In both cases the power P supplied to the station antenna and the wave-length must be made the same. Then, approximately, $$\text{Efficiency} = \eta_\alpha = i_1^2 \frac{I_1^2 - I_2^2}{I_1^2 i_2^2 - I_2^2 i_1^2}.$$ Also if R be joulean resistance, and r be radiation of the antenna—earth circuit $$R = P \frac{i_2^2 - i_1^2}{I_1^2 i_2^2 - I_2^2 i_1^2}$$ $$r = P \frac{i_1^2}{I_1^2} \cdot \frac{I_1^2 - I_2^2}{I_1^2 i_2^2 - I_2^2 i_1^2}.$$ [Erskine-Murray.]	$P = 2\pi n \delta L I^2$, where L is the inductance of the antenna. These formulæ are subject to some small corrections not given here.

23. Distance between two points on the earth's surface.	For very long distances, map measurements have no accurate meaning, and formulæ must be sued for their accurate determination. Let θ and α be lat. and long. of station A. „ θ' and α' be lat. and long. of station B. „ ϕ be the angle subtended by the arc AB at the centre of the earth. Then, either— (i.) $\text{Cos}\ \phi = \sin\theta\sin\theta' + \cos\theta\cos\alpha\cos\theta'\cos\alpha' + \cos\theta\sin\alpha\cos\theta'\sin\alpha'$, or (ii.) $\text{Hav}\ \phi = \text{hav}\left[(90^\circ - \theta) - (90^\circ - \theta')\right] + \text{have}\begin{bmatrix}\text{difference of}\\ \text{longitude}\end{bmatrix}\sin\left(90^\circ - \theta\right)\sin\left(90^\circ - \theta'\right)$ can be used for evaluating ϕ. Taking earth's radius as 3,440 miles, Distance of A from B $$d = 2\pi 3440\,\frac{\phi}{360} = 60\phi \text{ miles.}$$ where ϕ is in degrees and decimals of a degree.	See Table 6 for Haversines (page 38). Example 8 (page 75).
24. Current and Voltage relations in Oscillatory Circuits.	Let I_{RMS} and I_{max} = current in ampères. V_{RMS} and V_{max} = pressure in volts. δ = log. dec. per half period. n = frequency of oscillations per second. N = spark train frequency per second (with disc discharger with one stud per pole $N = 2f$ where f is the alternator frequency). K = capacity in farads.	

SUBJECT.	FORMULA.	NOTES.
	Then $V_{RMS} = \frac{I_{RMS}}{2\pi n K} = V_{max}\sqrt{\frac{N}{8n\delta}}$. $I_{RMS} = \frac{V_{RMS}}{2\pi n K} = I_{max}\sqrt{\frac{N}{8n\delta}}$. $V_{max} = \frac{I_{max}}{2\pi n K} = V_{RMS}\sqrt{\frac{8n\delta}{N}}$. $I_{max} = \frac{V_{max}}{2\pi n K} = I_{RMS}\sqrt{\frac{8n\delta}{N}}$.	
25. Rope, Strength of . .	Rough rule for all cordage except coir. Safe working = c^2 cwts., where c = circumference in inches. ,, ,, for wire ropes (hemp core) = $9c^2$ cwts. ,, ,, steel rope (wire core) = $16c^2$ cwts.	These are only roughly approximate. ,, ,, ,, ,, ,, ,,
26. Elongation of Stays. .	All-wire rope. Elongation $0{\cdot}25 \times S/c^2$ % Wire rope with one main hemp core. ,, $0{\cdot}3 \times S/c^2$ % Wire rope with main hemp core, and hemp core in each strand. ,, $0{\cdot}5 \times S/c^2$ %	S = load in tons. c = circumference in inches.
27. Tension in Stays . .	T = tension in lbs. w = lbs. per foot of stay. a = distance from anchor point to foot of mast (in feet). b = height of stay attachment (in feet). c = height of intersection of tangent to stay at the ground and mast (in feet). $T = w\frac{a^2 + c^2}{2(b - c)}$ lbs.	Example 23 (page 95).

28. Approximate Weight of Wire Rope.	Weight in lbs. per fathom = square of circumference in inches.	
29. Length of bare Wire on a Bobbin.	D = diam. of bobbin in inches. l = length of bobbin in inches (inside). d = diam. of core in inches. δ = diam. of wire in mils. 1 mil. = ·001 inch. L = length of wire on bobbin in yards. $L = 21{,}820 \frac{l}{\delta^2} (D^2 - d^2)$ yards.	Example 24 (page 95).
30. Centrifugal Force . .	F = radial force acting on given mass m (lbs.). r = radius of centre of mass considered (feet). m = mass considered (lbs.). $F = 0{\cdot}00034\ r\ .\ m.\ (\text{R.P.M.})^2$.	See Example 10 (page 76).
31. Pull of an Iron Cored Solenoid.	B_g = density in air gap in lines per sq. cms. = 1·257 = amp. turns per cm. length of gap. A_g = Area of gap in sq. cms. P = pull in kilogrs. Then $P = \frac{B_g{}^2 A_g}{8\pi 981{,}000}$ kilogrs.	See Example 18 (page 86).
32. Inductance of Solenoid .	t = number of turns on solenoid. ϕ = total flux = $B_g \times A_g$. I = magnetising current in amps. L = inductance of solenoid in henries. $L = \frac{0{\cdot}707}{10^3} \frac{t \times \phi}{I}$ henries. [NOTE.—Instantaneous pull for any given circuit conditions at given time t_1 secs. after closing circuit is obtained by using	

SUBJECT.	FORMULA.	NOTES.
	$i = \frac{E}{R}\left(1 - \epsilon^{-\frac{Rt}{L}}\right)$ for the current i at time t where E = E.M.F. in volts, R = resistance of circuit in ohms, L = inductance in henries of total circuit.] N.B.—This last note takes no account of magnetic lag. This is diminished though not eliminated by fine laminations of the iron circuit and absence of solid metallic masses near the magnetic circuit.	
33. Strength of Materials .	WORKING STRESSES.	
Mild or structural steel .	Tension. 6 — Compression. 6 — Shear 3·7 tons per sq. inch.	
Oregon fir	1,200 — 1,200 with grain, 300 across „ — lbs. per sq. inch. „ „	
Red pine	900 — 800 with grain, 200 across „ — „ „	
Materials	(see table below)	Stresses in tons per sq. inch

Material.	Weight of 1 cubic inch.	Stresses. Tensile.	Stresses. Shearing.	Stresses. Crushing.
Aluminium . .	0·096	12	—	—
Copper bolts . .	0·318	17–24	—	—
Copper sheets . .	0·316	13·4	—	—
Iron, Cast . .	0·26	7·3	14	48
Iron, Wrought . .	0·28	22	20	16·9
Steel, Cast . .	0·288	52	—	—
Steel, Mild . .	0·283	30	30	30

1 Atmosphere = 14·7 lbs. per sq. inch.
= 1 kilogram per sq. cm.

1 Radian = 57·29°.

ϵ = (base of Napierian logs) = 2·7183.

Common log × 2·3026 = Napierian log.

A man can work about $\frac{1}{8}$ h.p.

For other data see Tables following.

SECTION II

TABLE I.

Four Figure Table of Common Logarithms.

LOGARITHMS.

No.	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0710						4	9	13	17	21	26	30	34	38
						0212	0253	0294	0334	0374	4	8	12	16	20	24	28	32	36
11	0414	0453	0492	0531	0569						4	8	12	15	19	23	27	31	35
						0607	0645	0682	0719	0755	4	7	11	15	19	22	26	30	33
12	0792	0828	0864	0899	0934						3	7	11	14	18	21	25	28	32
						0969	1004	1038	1072	1106	3	7	10	14	17	20	24	27	31
13	1139	1173	1206	1239	1270						3	7	10	13	16	20	23	26	30
						1303	1335	1367	1399	1430	3	7	10	13	16	19	22	25	29
14	1461	1492	1523	1553	1584						3	6	9	12	15	19	22	25	28
						1614	1644	1673	1703	1732	3	6	9	12	15	17	20	23	26
15	1761	1790	1818	1847	1875						3	6	9	11	14	17	20	23	26
						1903	1931	1959	1987	2014	3	6	8	11	14	17	19	22	25
16	2041	2068	2095	2122	2148						3	5	8	11	14	16	19	22	24
						2175	2201	2227	2253	2279	3	5	8	10	13	16	18	21	23
17	2304	2330	2355	2380	2405						3	5	8	10	13	15	18	20	23
						2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648						2	5	7	9	12	14	16	19	21
						2672	2695	2718	2742	2765	2	5	7	9	11	14	16	18	21
19	2788	2810	2833	2856	2878						2	4	7	9	11	13	16	18	20
						2900	2923	2945	2967	2989	2	4	6	8	11	13	15	17	19
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6322	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8

LOGARITHMS.

No.	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

TABLE 2.

FOUR FIGURE TABLE OF NATURAL LOGS. OF NUMBERS FROM 1 TO 100.

Number.	$\text{Log}_e\, n$.	Difference.	Number.	$\text{Log}_e\, n$.	Difference.	Number.	$\text{Log}_e\, n$.	Difference.
1·0	0·0000	953	8·0	2·0794	248	19·0	2·9445	105
1·1	0·0953	870	8·2	2·1041	243	19·2	2·9550	104
1·2	0·1823	801	8·4	2·1284	236	19·4	2·9654	101
1·3	0·2624	741	8·6	2·1520	229	19·6	2·9755	101
1·4	0·3365	690	8·8	2·1749	223	19·8	2·9856	101
1·5	0·1055	650	9·0	2·1972	219	20·0	2·9957	100
1·6	0·4705	604	9·2	2·2191	216	20·2	3·0057	100
1·7	0·5309	570	9·4	2·2407	212	20·4	3·0157	97
1·8	0·5879	540	9·6	2·2619	206	20·6	3·0254	96
1·9	0·6419	513	9·8	2·2825	201	20·8	3·0350	95
2·0	0·6932	488	10·0	2·3026	199	21·0	3·0445	95
2·1	0·7420	465	10·2	2·3225	195	21·2	3·0540	94
2·2	0·7885	445	10·4	2·3420	191	21·4	3·0634	92
2·3	0·8330	426	10·6	2·3611	185	21·6	3·0726	92
2·4	0·8756	407	10·8	2·3796	183	21·8	3·0818	92
2·5	0·9163	392	11·0	2·3979	179	22·0	3·0910	92
2·6	0·9555	377	11·2	2·4158	175	22·2	3·1002	90
2·7	0·9932	364	11·4	2·4333	174	22·4	3·1092	89
2·8	1·0296	351	11·6	2·4507	172	22·6	3·1181	87
2·9	1·0647	339	11·8	2·4679	170	22·8	3·1268	87
3·0	1·0986	328	12·0	2·4849	165	33·0	3·1355	87
3·1	1·1314	318	12·2	2·5014	163	23·2	3·1442	86
3·2	1·1632	309	12·4	2·5177	160	23·4	3·1528	85
3·3	1·1941	299	12·6	2·5337	158	23·6	3·1613	84
3·4	1·2240	290	12·8	2·5495	155	23·8	3·1697	84
3·5	1·2530	281	13·0	2·5650	153	24·0	3·1781	83
3·6	1·2811	273	13·2	2·5803	150	24·2	3·1864	82
3·7	1·3084	266	13·4	2·5953	148	24·4	3·1946	82
3·8	1·3350	260	13·6	2·6101	146	24·6	3·2028	81
3·9	1·3610	253	13·8	2·6247	144	24·8	3·2109	80
4·0	1·3863	247	14·0	2·6391	142	25·0	3·2189	198
4·1	1·4110	242	14·2	2·6533	140	25·5	3·2387	194
4·2	1·4352	235	14·4	2·6673	138	26·0	3·2581	190
4·3	1·4587	229	14·6	2·6811	136	26·5	3·2771	187
4·4	1·4816	224	14·8	2·6947	133	27·0	3·2958	184
4·5	1.5040	220	15·0	2·7080	133	27·5	3·3142	180
4·6	1·5260	217	15·2	2·7213	131	28·0	3·3322	177
4·7	1·5477	211	15·4	2·7344	129	28·5	3·3499	174
4·8	1·5688	206	15·6	2·7473	127	29·0	3·3673	170
4·9	1·5894	200	15·8	2·7600	126	29·5	3·3843	169
5·0	1·6094	392	16·0	2·7726	124	30·0	3·4012	165
5·2	1·6486	378	16·2	2·7850	123	30·5	3·4177	163
5·4	1·6864	367	16·4	2·7973	122	31·0	3·4340	160
5·6	1·7231	348	16·6	2·8095	120	31·5	3·4500	157
5·8	1·7579	338	16·8	2·8215	117	32·0	3·4657	155
6·0	1·7917	328	17·0	2·8332	117	32·5	3·4812	153
6·2	1·8245	318	17·2	2·8449	116	33·0	3·4965	151
6·4	1·8563	308	17·4	2·8565	115	33·5	3·5116	148
6·6	1·8871	298	17·6	2·8680	112	34·0	3·5264	146
6·8	1·9169	290	17·8	2·8792	112	34·5	3·5410	144
7·0	1·9459	283	18·0	2·8904	110	35·5	3·5554	142
7·2	1·9742	274	18·2	2·9014	109	35·5	3·5696	139
7·4	2·0016	266	18·4	2·9123	108	36·0	3·5835	137
7·6	2·0282	259	18·6	2·9231	107	36·5	3·5972	137
7·8	2·0541	252	18·8	2·9338	107	37·0	3·6109	135
8·0	2·0794	248	19·0	2·9445	105	37·5	3·6244	132

TABLE 2—*continued.*

Number.	Log$_\epsilon$ n.	Difference.	Number.	Log$_\epsilon$ n.	Difference.	Number.	Log$_\epsilon$ n.	Difference.
37·5	3·6244	132	72	4·2767	138	290	5·6700	339
38·0	3·6376	131	73	4·2905	136	300	5·7039	329
38·5	3·6507	129	74	4·3041	134	310	5·7368	316
39·0	3·6636	128	75	4·3175	132	320	5·7684	309
39·5	3·6764	126	76	4·3307	131	330	5·7993	299
40·0	3·6890	124	77	4·3438	129	340	5·8292	289
40·5	3·7014	122	78	4·3567	127	350	5·8581	281
41·0	3·7136	121	79	4·3694	126	360	5·8862	271
41·5	3·7257	120	80	4·3820	124	370	5·9133	267
42·0	3·7377	118	81	4·3944	123	380	5·9400	261
42·5	3·7495	117	82	4·4067	121	390	5·9661	255
43·0	3·7612	115	83	4·4188	120	400	5·9916	247
43·5	3·7727	115	84	4·4308	118	410	6·0163	241
44·0	3·7842	113	85	4·4426	117	420	6·0404	237
44·5	3·7955	112	86	4·4543	116	430	6·0641	231
45·0	3·8067	110	87	4·4659	114	440	6·0872	225
45·5	3·8177	109	88	4·4773	113	450	6·1097	219
46·0	3·8286	108	89	4·4886	112	460	6 1316	214
46·5	3·8394	108	90	4·4998	111	470	6·1530	209
47·0	3·8502	106	91	4·5109	109	480	6·1739	205
47·5	3·8608	104	92	4·5218	108	490	6·1944	200
48·0	3·8712	104	93	4·5326	107	500	6·2144	390
48·5	3·8816	102	94	4·5433	106	520	6·2538	380
49·0	3·8918	102	95	4·5539	105	540	6·2918	364
49·5	3·9020	100	96	4·5644	103	560	6·3282	350
50·0	3·9120	198	97	4·5747	103	580	6·3632	340
51	3·9318	194	98	4·5850	101	600	6·3972	328
52	3·9512	191	99	4·5951	101	620	6·4300	317
53	3·9703	187	100	4·6052	955	640	6·4617	305
54	3·9890	183	110	4·7007	871	660	6·4922	294
55	4·0073	180	120	4·7878	800	680	6·5216	289
56	4·0253	177	130	4·8678	739	700	6·5505	285
57	4·0430	174	140	4·9417	691	720	6·5790	278
58	4·0604	171	150	5·0108	645	740	6·6068	268
59	4·0775	168	160	5·0753	606	760	6·6336	260
60	4·0943	166	170	5·1359	570	780	6·6596	254
61	4·1109	162	180	5·1929	541	800	6·6850	249
62	4·1271	160	190	5·2470	513	820	6·7099	241
63	4·1431	158	200	5·2983	489	840	6·7340	236
64	4·1589	155	210	5·3472	465	860	6·7576	230
65	4·1744	153	220	5·3937	441	880	6·7806	224
66	4·1897	150	230	5·4378	430	900	6·8030	218
67	4·2047	148	240	5·4808	404	920	6·8248	213
68	4·2195	146	250	5·5212	393	940	6·8461	210
69	4·2341	144	260	5·5605	381	960	6·8671	206
70	4·2485	142	270	5·5986	364	980	6·8877	200
71	4·2627	140	280	5·6359	350	1000	6·9077	
72	4·2767	138	290	5·6700	339			

TABLE 3.

Four Figure Table of Natural Sines.

NATURAL SINES.

Deg.	0′	10′	20′	30′	40′	50′	1	2	3	4	5	6	7	8	9
0	0000	0029	0058	0087	0116	0145	3	6	9	12	15	17	20	23	26
1	0175	0204	0233	0262	0291	0320	3	6	9	12	15	17	20	23	26
2	0349	0378	0407	0436	0465	0494	3	6	9	12	15	17	20	23	26
3	0523	0552	0581	0610	0640	0669	3	6	9	12	15	17	20	23	26
4	0698	0727	0756	0785	0814	0843	3	6	9	12	15	17	20	23	26
5	0872	0901	0929	0958	0987	1016	3	6	9	12	14	17	20	23	26
6	1045	1074	1103	1132	1161	1190	3	6	9	12	14	17	20	23	26
7	1219	1248	1276	1305	1334	1363	3	6	9	12	14	17	20	23	26
8	1392	1421	1449	1478	1507	1536	3	6	9	12	14	17	20	23	26
9	1564	1593	1622	1650	1679	1708	3	6	9	12	14	17	20	23	26
10	1736	1765	1794	1822	1851	1880	3	6	9	12	14	17	20	23	26
11	1908	1937	1965	1994	2022	2051	3	6	9	11	14	17	20	23	26
12	2079	2108	2136	2164	2193	2221	3	6	9	11	14	17	20	23	26
13	2250	2278	2306	2334	2363	2391	3	6	8	11	14	17	20	23	25
14	2419	2147	2476	2504	2532	2560	3	6	8	11	14	17	20	23	25
15	2588	2616	2644	2672	2700	2728	3	6	8	11	14	17	20	22	25
16	2756	2784	2812	2840	2868	2896	3	6	8	11	14	17	20	22	25
17	2924	2952	2979	3007	3035	3062	3	6	8	11	14	17	19	22	25
18	3090	3118	3145	3173	3201	3228	3	6	8	11	14	17	19	22	25
19	3256	3283	3311	3338	3365	3393	3	5	8	11	14	16	19	22	25
20	3420	3448	3475	3502	3529	3557	3	5	8	11	14	16	19	22	25
21	3584	3611	3638	3665	3692	3719	3	5	8	11	14	16	19	22	24
22	3746	3773	3800	3827	3854	3881	3	5	8	11	14	16	19	21	24
23	3907	3934	3961	3987	4014	4041	3	5	8	11	14	16	19	21	24
24	4067	4094	4120	4147	4173	4200	3	5	8	11	13	16	19	21	24
25	4226	4253	4278	4305	4331	4358	3	5	8	11	13	16	18	21	24
26	4384	4410	4436	4462	4488	4514	3	5	8	10	13	16	18	21	23
27	4540	4566	4592	4617	4643	4669	3	5	8	10	13	15	18	21	23
28	4695	4720	4746	4772	4797	4823	3	5	8	10	13	15	18	20	23
29	4848	4874	4899	4924	4950	4975	3	5	8	10	13	15	18	20	23
30	5000	5025	5050	5075	5100	5125	3	5	8	10	13	15	18	20	23
31	5150	5175	5200	5225	5250	5275	2	5	7	10	12	15	17	20	22
32	5299	5324	5348	5373	5398	5422	2	5	7	10	12	15	17	20	22
33	5446	5471	5495	5519	5544	5568	2	5	7	10	12	15	17	19	22
34	5592	5616	5640	5664	5688	5712	2	5	7	10	12	14	17	19	22
35	5736	5760	5783	5807	5831	5854	2	5	7	10	12	14	17	19	21
36	5878	5901	5925	5948	5972	5995	2	5	7	9	12	14	16	19	21
37	6018	6041	6065	6088	6111	6134	2	5	7	9	12	14	16	18	21
38	6157	6180	6202	6225	6248	6271	2	5	7	9	11	14	16	18	20
39	6293	6316	6338	6361	6383	6406	2	4	7	9	11	13	16	18	20
40	6428	6450	6472	6494	6517	6539	2	4	7	9	11	13	15	18	20
41	6561	6583	6604	6626	6648	6670	2	4	7	9	11	13	15	17	20
42	6691	6713	6734	6756	6777	6799	2	4	6	9	11	13	15	17	19
43	6820	6841	6862	6884	6905	6926	2	4	6	8	11	13	15	17	19
44	6947	6967	6988	7009	7030	7050	2	4	6	8	10	12	15	17	19

TABLE 3—*continued.*

NATURAL SINES.

Deg.	0′	10′	20′	30′	40′	50′	1	2	3	4	5	6	7	8	9
45	7071	7092	7112	7133	7153	7173	2	4	6	8	10	12	14	16	18
46	7193	7214	7234	7254	7274	7294	2	4	6	8	10	12	14	16	18
47	7314	7333	7353	7373	7392	7412	2	4	6	8	10	12	14	16	18
48	7431	7451	7470	7490	7509	7528	2	4	6	8	10	12	13	15	17
49	7547	7566	7585	7604	7623	7642	2	4	6	8	9	11	13	15	17
50	7660	7679	7698	7716	7735	7753	2	4	6	7	9	11	13	15	17
51	7771	7790	7808	7826	7844	7862	2	4	5	7	9	11	13	14	16
52	7880	7898	7916	7934	7951	7969	2	4	5	7	9	11	12	14	16
53	7986	8004	8021	8039	8056	8073	2	3	5	7	9	10	12	14	16
54	8090	8107	8124	8141	8158	8175	2	3	5	7	8	10	12	14	15
55	8192	8208	8225	8241	8258	8274	2	3	5	7	8	10	12	13	15
56	8290	8307	8323	8339	8355	8371	2	3	5	6	8	10	11	13	14
57	8387	8403	8418	8434	8450	8465	2	3	5	6	8	9	11	12	14
58	8480	8496	8511	8526	8542	8557	2	3	4	6	8	9	11	12	14
59	8572	8587	8601	8616	8631	8646	1	3	4	6	7	9	10	12	13
60	8660	8675	8689	8704	8718	8732	1	3	4	6	7	9	10	11	13
61	8746	8760	8774	8788	8802	8816	1	3	4	6	7	8	10	11	12
62	8829	8843	8857	8870	8884	8897	1	3	4	5	7	8	9	11	12
63	8910	8923	8936	8949	8962	8975	1	3	4	5	6	8	9	10	12
64	8988	9001	9013	9026	9038	9051	1	3	4	5	6	8	9	10	11
65	9063	9075	9088	8100	9112	9124	1	2	4	5	6	7	8	10	11
66	9135	9147	9159	9171	9182	9194	1	2	3	5	6	7	8	9	10
67	9205	9216	9228	9239	9250	9261	1	2	3	4	6	7	8	9	10
68	9272	9283	9293	9304	9315	9325	1	2	3	4	5	6	7	9	10
69	9336	9346	9356	9367	9377	9387	1	2	3	4	5	6	7	8	9
70	9397	9407	9417	9426	9436	9446	1	2	3	4	5	6	7	8	9
71	9455	9465	9474	9483	9492	9502	1	2	3	4	5	6	6	7	8
72	9511	9520	9528	9537	9546	9555	1	2	3	4	4	5	6	7	8
73	9563	9572	9580	9588	9596	9605	1	2	2	3	4	5	6	7	7
74	9613	9621	9628	9636	9644	9652	1	2	2	3	4	5	5	6	7
75	9659	9667	9674	9681	9689	9696	1	1	2	3	4	4	5	6	7
76	9703	9710	9717	9724	9730	9737	1	1	2	3	3	4	5	5	6
77	9744	9750	9757	9763	9769	9775	1	1	2	3	3	4	4	5	6
78	9781	9787	9793	9799	9805	9811	1	1	2	2	3	3	4	5	5
79	9816	9822	9827	9833	9838	9843	1	1	2	2	3	3	4	4	5
80	9848	9853	9858	9863	9868	9872	0	1	1	2	2	3	3	4	4
81	9877	9881	9886	9890	9894	9899	0	1	1	2	2	3	3	3	4
82	9903	9907	9911	9914	9918	9922	0	1	1	2	2	2	3	3	3
83	9925	9929	9932	9936	9939	9942	0	1	1	1	2	2	3	3	3
84	9945	9948	9951	9954	9957	9959	0	1	1	1	1	2	2	2	2
85	9962	9964	9967	9969	9971	9974	0	0	1	1	1	1	2	2	2
86	9976	9978	9980	9981	9983	9985	0	0	1	1	1	1	1	1	2
87	9986	9988	9989	9990	9992	9993	0	0	0	1	1	1	1	1	1
88	9994	9995	9996	9997	9997	9998	0	0	0	0	0	0	1	1	1
89	9998	9999	9999	1·0000	1·0000	1·0000	0	0	0	0	0	0	0	0	0

TABLE 4.

Four Figure Table of Natural Cosines.

NATURAL COSINES.

Deg.	0′	10′	20′	30′	40′	50′	1	2	3	4	5	6	7	8	9
0	1·0000	1·0000	1·0000	1·0000	9999	9999	0	0	0	0	0	0	0	0	0
1	9998	9998	9997	9997	9996	9995	0	0	0	0	0	0	0	0	0
2	9994	9993	9992	9990	9989	9988	0	0	0	0	0	0	1	1	1
3	9986	9985	9983	9981	9980	9978	0	0	1	1	1	1	1	1	1
4	9976	9974	9971	9969	9967	9964	0	0	1	1	1	1	1	1	2
5	9962	9959	9957	9954	9951	9948	0	1	1	1	1	1	2	2	2
6	9945	9942	9939	9936	9932	9929	0	1	1	1	2	2	2	2	2
7	9925	9922	9918	9914	9911	9907	0	1	1	2	2	2	3	3	3
8	9903	9899	9894	9890	9886	9881	0	1	1	2	2	2	3	3	3
9	9877	9872	9868	9863	9858	9853	0	1	1	2	2	3	3	3	4
10	9848	9843	9838	9833	9827	9822	1	1	2	2	2	3	3	4	4
11	9816	9811	9805	9799	9793	9787	1	1	2	2	3	3	4	4	5
12	9781	9775	9769	9763	9757	9750	1	1	2	2	3	3	4	5	5
13	9744	9737	9730	9724	9717	9710	1	1	2	3	3	4	4	5	6
14	9703	9696	9689	9681	9674	9667	1	1	2	3	4	4	5	5	6
15	9659	9652	9644	9636	9628	9621	1	2	2	3	4	4	5	6	7
16	9613	9605	9596	9588	9580	9572	1	2	2	3	4	5	5	6	7
17	9563	9555	9546	9537	9528	9520	1	2	3	3	4	5	6	7	7
18	9511	9502	9492	9483	9474	9465	1	2	3	4	4	5	6	7	8
19	9455	9446	9436	9426	9417	9407	1	2	3	4	5	6	6	7	8
20	9397	9387	9377	9367	9356	9346	1	2	3	4	5	6	7	8	9
21	9336	9325	9315	9304	9293	9283	1	2	3	4	5	6	7	8	9
22	9272	9261	9250	9239	9228	9216	1	2	3	4	6	6	7	9	10
23	9205	9194	9182	9171	9159	9147	1	2	3	5	6	7	8	9	10
24	9135	9124	9112	9100	9088	9075	1	2	4	5	6	7	8	9	10
25	9063	9051	9038	9026	9013	9001	1	3	4	5	6	7	8	10	11
26	8988	8975	8962	8949	8936	8923	1	3	4	5	6	8	9	10	11
27	8910	8897	8884	8870	8857	8843	1	3	4	5	7	8	9	10	12
28	8829	8816	8802	8788	8774	8760	1	3	4	6	7	8	9	11	12
29	8746	8732	8718	8704	8689	8675	1	3	4	6	7	8	10	11	12
30	8660	8646	8631	8616	8601	8587	1	3	4	6	7	9	10	11	13
31	8572	8557	8542	8526	8511	8496	2	3	5	6	8	9	10	12	13
32	8480	8465	8450	8434	8418	8403	2	3	5	6	8	9	11	12	14
33	8387	8371	8355	8339	8323	8307	2	3	5	6	8	9	11	12	14
34	8290	8274	8258	8241	8225	8208	2	3	5	7	8	10	11	13	14
35	8192	8175	8158	8141	8124	8107	2	3	5	7	8	10	12	13	15
36	8090	8073	8056	8039	8021	8004	2	3	5	7	9	10	12	14	15
37	7986	7969	7951	7934	7916	7898	2	4	5	7	9	10	12	14	16
38	7880	7862	7844	7826	7808	7790	2	4	5	7	9	11	12	14	16
39	7771	7753	7735	7716	7698	7679	2	4	6	7	9	11	13	14	16
40	7660	7642	7623	7604	7585	7566	2	4	6	8	9	11	13	15	17
41	7547	7528	7509	7490	7470	7451	2	4	6	8	10	11	13	15	17
42	7431	7412	7392	7373	7353	7333	2	4	6	8	10	12	13	15	17
43	7314	7294	7274	7254	7234	7214	2	4	6	8	10	12	14	16	18
44	7193	7173	7153	7132	7112	7092	2	4	6	8	10	12	14	16	18

TABLE 4—*continued.*

NATURAL COSINES.

Deg.	0′	10′	20′	30′	40′	50′	1	2	3	4	5	6	7	8	9
45	7071	7050	7030	7009	6988	6967	2	4	6	8	10	12	15	17	19
46	6947	6926	6905	6884	6862	6841	2	4	6	8	11	13	15	17	19
47	6820	6799	6777	6756	6734	6713	2	4	6	9	11	13	15	17	19
48	6691	6670	6648	6626	6604	6583	2	4	7	9	11	13	15	17	19
49	6561	6539	6517	6494	6472	6450	2	4	7	9	11	13	15	17	20
50	6428	6406	6383	6361	6338	6316	2	4	7	9	11	13	15	18	20
51	6293	6271	6248	6225	6202	6180	2	5	7	9	11	13	16	18	20
52	6157	6134	6111	6088	6065	6041	2	5	7	9	12	14	16	18	20
53	6018	5995	5972	5948	5925	5901	2	5	7	9	12	14	16	18	21
54	5878	5854	5831	5807	5783	5760	2	5	7	9	12	14	16	19	21
55	5736	5712	5688	5664	5640	5616	2	5	7	10	12	14	17	19	21
56	5592	5568	5544	5519	5495	5471	2	5	7	10	12	14	17	19	22
57	5446	5422	5398	5373	5348	5324	2	5	7	10	12	15	17	19	22
58	5299	5275	5250	5225	5200	5175	2	5	7	10	12	15	17	20	22
59	5150	5125	5100	5075	5050	5025	3	5	8	10	13	15	17	20	22
60	5000	4975	4950	4924	4899	4874	3	5	8	10	13	15	18	20	23
61	4848	4823	4797	4772	4746	4720	3	5	8	10	13	15	18	20	23
62	4695	4669	4643	4617	4592	4566	3	5	8	10	13	15	18	20	23
63	4540	4514	4488	4462	4436	4410	3	5	8	10	13	15	18	21	23
64	4384	4358	4331	4305	4279	4253	3	5	8	11	13	16	18	21	23
65	4226	4200	4173	4147	4120	4094	3	5	8	11	13	16	18	21	24
66	4067	4041	4014	3987	3961	3934	3	5	8	11	14	16	19	21	24
67	3907	3881	3854	3827	3800	3773	3	5	8	11	14	16	19	21	24
68	3746	3719	3692	3665	3638	3611	3	5	8	11	14	16	19	21	24
69	3584	3557	3529	3502	3475	3448	3	5	8	11	14	16	19	22	24
70	3420	3393	3365	3338	3311	3283	3	5	8	11	14	16	19	22	25
71	3256	3228	3201	3173	3145	3118	3	6	8	11	14	16	19	22	25
72	3090	3062	3035	3007	2979	2952	3	6	8	11	14	17	19	22	25
73	2924	2896	2868	2840	2812	2784	3	6	8	11	14	17	19	22	25
74	2756	2728	2700	2672	2644	2616	3	6	8	11	14	17	20	22	25
75	2588	2560	2532	2504	2476	2447	3	6	8	11	14	17	20	22	25
76	2419	2391	2363	2334	2306	2278	3	6	8	11	14	17	20	23	25
77	2250	2221	2193	2164	2136	2108	3	6	9	11	14	17	20	23	25
78	2079	2051	2022	1994	1965	1937	3	6	9	11	14	17	20	23	26
79	1908	1880	1851	1822	1794	1765	3	6	9	12	14	17	20	23	26
80	1736	1708	1679	1650	1622	1593	3	6	9	12	14	17	20	23	26
81	1564	1536	1507	1478	1449	1421	3	6	9	12	14	17	20	23	26
82	1392	1363	1334	1305	1276	1248	3	6	9	12	14	17	20	23	26
83	1219	1190	1161	1132	1103	1074	3	6	9	12	14	17	20	23	26
84	1045	1016	0987	0958	0929	0901	3	6	9	12	14	17	20	23	26
85	0872	0843	0814	0785	0756	0727	3	6	9	12	15	17	20	23	26
86	0698	0669	0640	0610	0581	0552	3	6	9	12	15	17	20	23	26
87	0523	0494	0465	0436	0407	0378	3	6	9	12	15	17	20	23	26
88	0349	0320	0291	0262	0233	0204	3	6	9	12	15	17	20	23	26
89	0175	0145	0116	0087	0058	0029	3	6	9	12	15	17	20	23	26

TABLE 5.

Four Figure Table of Natural Tangents.

NATURAL TANGENTS.

Deg.	0′	5′	10′	15′	20′	25′	30′	35′	40′	45′	50′	55′	1	2	3	4
0°	·0000	0015	0029	0044	0058	0073	0087	0102	0116	0131	0145	0160	3	6	9	12
1	·0175	0189	0204	0218	0233	0247	0262	0276	0291	0306	0320	0335	3	6	9	12
2	·0349	0364	0378	0393	0407	0422	0437	0451	0466	0480	0495	0509	3	6	9	12
3	·0524	0539	0553	0568	0582	0597	0612	0626	0641	0655	0670	0685	3	6	9	12
4	·0699	0714	0729	0743	0758	0772	0787	0802	0816	0831	0846	0860	3	6	9	12
5	·0875	0890	0904	0919	0934	0948	0963	0978	0992	1007	1022	1036	3	6	9	12
6	·1051	1066	1080	1095	1110	1125	1139	1154	1169	1184	1198	1213	3	6	9	12
7	·1228	1243	1257	1272	1287	1302	1317	1331	1346	1361	1376	1391	3	6	9	12
8	·1405	1420	1435	1450	1465	1480	1495	1509	1524	1539	1554	1569	3	6	9	12
9	·1584	1599	1614	1629	1644	1658	1673	1688	1703	1718	1733	1748	3	6	9	12
10	·1763	1778	1793	1808	1823	1838	1853	1868	1883	1899	1914	1929	3	6	9	12
11	·1944	1959	1974	1989	2004	2019	2035	2050	2065	2080	2095	2110	3	6	9	12
12	·2126	2141	2156	2171	2186	2202	2217	2232	2247	2263	2278	2293	3	6	9	12
13	·2309	2324	2339	2355	2370	2385	2401	2416	2432	2447	2462	2478	3	6	9	12
14	·2493	2509	2524	2540	2555	2571	2586	2602	2617	2633	2648	2664	3	6	9	12
15	·2679	2695	2711	2726	2742	2758	2773	2789	2805	2820	2836	2852	3	6	9	13
16	·2867	2883	2899	2915	2931	2946	2962	2978	2994	3010	3026	3041	3	6	9	13
17	·3057	3073	3089	3106	3121	3137	3153	3169	3185	3201	3217	3233	3	6	10	13
18	·3249	3265	3281	3298	3314	3330	3346	3362	3378	3395	3411	3427	3	6	10	13
19	·3443	3460	3476	3492	3508	3525	3541	3558	3574	3590	3607	3623	3	6	10	13
20	·3640	3656	3673	3689	3706	3722	3739	3755	3772	3789	3805	3822	3	7	10	13
21	·3839	3855	3872	3889	3906	3922	3939	3956	3973	3990	4006	4023	3	7	10	13
22	·4040	4057	4074	4091	4108	4125	4142	4159	4176	4193	4210	4228	3	7	10	14
23	·4245	4262	4279	4296	4314	4331	4348	4365	4383	4400	4417	4435	3	7	10	14
24	·4452	4470	4487	4505	4522	4540	4557	4575	4592	4610	4628	4645	4	7	10	14
25	·4663	4681	4699	4716	4734	4752	4770	4788	4806	4823	4841	4859	4	7	11	14
26	·4877	4895	4913	4931	4950	4968	4986	5004	5022	5040	5059	5077	4	7	11	15
27	·5095	5114	5132	5150	5169	5187	5206	5224	5243	5261	5280	5298	4	7	11	15
28	·5317	5336	5354	5373	5392	5411	5430	5448	5467	5486	5505	5524	4	8	11	15
29	·5543	5562	5580	5600	5619	5639	5658	5677	5696	5715	5735	5754	4	8	12	15
30	·5774	5793	5812	5832	5851	5871	5890	5910	5930	5949	5969	5989	4	8	12	16
31	·6009	6028	6048	6068	6088	6108	6128	6148	6168	6188	6208	6228	4	8	12	16
32	·6249	6269	6289	6310	6330	6350	6371	6391	6412	6432	6453	6473	4	8	12	16
33	·6494	6515	6536	6556	6577	6598	6609	6640	6661	6682	6703	6724	4	8	13	17
34	·6745	6766	6787	6809	6830	6851	6873	6894	7916	6937	6959	6980	4	9	13	17
35	·7002	7024	7046	7067	7089	7111	7133	7155	7177	7199	7221	7243	4	9	13	18
36	·7265	7288	7310	7332	7355	7377	7400	7422	7445	7467	7490	7513	5	9	14	18
37	·7536	7558	7580	7604	7627	7650	7673	7696	7720	7743	7766	7789	5	9	14	18
38	·7813	7836	7860	7883	7907	7931	7954	7978	8002	8026	8050	8074	5	10	14	19
39	·8098	8122	8146	8170	8195	8219	8243	8268	8292	8317	8342	8366	5	10	15	20
40	·8391	8416	8441	8466	8491	8516	8541	8566	8591	8617	8642	8667	5	10	15	20
41	·8693	8718	8744	8770	8796	8821	8847	8873	8899	8925	8952	8978	5	10	16	21
42	·9004	9030	9057	9083	9110	9137	9163	9190	8217	9244	9271	9298	5	11	16	21
43	·9325	9352	9380	9407	9435	9462	9490	9157	9545	9573	9601	9629	6	11	17	22
44	·9657	9685	9713	9742	9770	9798	9827	9856	9884	9913	9942	9971	6	11	17	23

TABLE 5—*continued.*

NATURAL TANGENTS.

Deg.	0′	5′	10′	15′	20′	25′	30′	35′	40′	45′	50′	55′	1	2	3	4
45°	1·000	0029	0058	0088	0117	0147	0176	0206	0235	0265	0295	0325	6	12	18	24
46	1·035	0385	0416	0446	0477	0507	0538	0569	0599	0630	0661	0692	6	12	18	25
47	1·072	0755	0786	0818	0850	0881	0913	0945	0977	1009	1041	1074	6	13	19	25
48	1·111	1139	1171	1204	1237	1270	1303	1336	1369	1403	1436	1470	7	13	20	26
49	1·150	1538	1571	1606	1640	1674	1708	1743	1778	1812	1847	1882	7	14	21	28
50	1·192	0953	1988	2024	2059	2095	2131	2167	2203	2239	2276	2312	7	14	22	29
51	1·235	2386	2423	2460	2497	2534	2572	2609	2647	2685	2723	2761	8	15	23	30
52	1·280	2838	2876	2915	2954	2993	3032	3072	3111	3151	3190	3230	8	16	23	31
53	1·327	3311	3351	3392	3432	3473	3514	3555	3597	3638	3680	3722	8	16	25	33
54	1·376	3806	3848	3891	3934	3976	4019	4063	4106	4150	4193	4237	9	17	26	34
55	1·428	4326	4370	4415	4460	4505	4550	4596	4641	4687	4733	4779	9	18	27	36
56	1·483	4872	4919	4966	5013	5061	5108	5156	5204	5253	5301	5350	10	19	29	38
57	1·540	5448	5497	5547	5597	5647	5697	5747	5798	5849	5900	5952	10	20	30	40
58	1·600	6055	6107	6160	6212	6265	6319	6372	6426	6479	6534	6558	11	21	32	43
59	1·664	6698	6753	6808	6864	6920	6977	7033	7090	7147	7205	7262	11	23	34	45
60	1·732	7379	7437	7496	7556	7615	7675	7735	7796	7856	7917	7979	12	24	36	48
61	1·804	8103	8165	8228	8291	8354	8418	8482	8546	8611	8676	8741	13	26	38	51
62	1·881	8873	8940	9007	9074	9142	9210	9278	9347	9416	9486	9556	14	27	41	55
63	1·963	9697	9768	9840	9912	9984	$\overline{0}057$	$\overline{0}130$	$\overline{0}204$	$\overline{0}278$	$\overline{0}353$	$\overline{0}428$	15	29	44	58
64	2·050	0579	0655	0732	0809	0887	0965	1044	1123	1203	1283	1364	16	31	47	63
65	2·144	1527	1609	1692	1775	1859	1943	2028	2113	2199	2286	2373	17	34	51	68
66	2·246	2549	2637	2727	2817	2907	2998	3090	3183	3276	3369	3464	18	37	55	74
67	2·356	3654	3750	3847	3945	4043	4142	4242	4342	4443	4545	4648	20	40	60	79
68	2·475	4855	4960	5065	5172	5279	5386	5495	5605	5715	5826	5938	22	43	65	87
69	2·605	6165	6279	6395	6511	6628	6746	6865	6985	7106	7228	7351	24	47	71	95
70	2·747	2·760	2·773	2·785	2·798	2·811	2·824	2·837	2·850	2·864	2·877	2·891	3	5	8	10
71	2·904	2·918	2·932	2·946	2·960	2·974	2·989	3·003	3·018	3·033	3·047	3·063	3	6	9	11
72	3·078	3·093	3·108	3·124	3·140	3·156	3·172	3·188	3·204	3·221	3·237	3·254	3	6	10	13
73	3·271	3·288	3·305	3·323	3·340	3·358	3·376	3·394	3·412	3·431	3·450	3·468	4	7	11	14
74	3·487	3·507	3·526	3·546	3·566	3·586	3·606	3·626	3·647	3·668	3·689	3·710	4	8	12	16
75	3·732	3·754	3·776	3·789	3·821	3·844	3·867	3·890	3·914	3·938	3·962	3·986	5	9	14	19
76	4·011	4·036	4·061	4·087	4·113	4·139	4·165	4·192	4·219	4·247	4·275	4·303	5	11	16	21
77	4·331	4·360	4·390	4·419	4·449	4·480	4·511	4·542	4·574	4·606	4·638	4·671	6	12	19	25
78	4·705	4·739	4·773	4·808	4·843	4·879	4·915	4·952	4·989	5·027	5·066	5·105	7	15	22	29
79	5·145	5·185	5·226	5·267	5·309	5·352	5·396	5·440	5·485	5·530	5·576	5·623	9	17	26	35
80	5·671	5·720	5·769	5·820	5·871	5·923	5·976	6·030	6·084	6·140	6·197	6·255				
81	6·314	6·374	6·435	6·497	6·561	6·625	6·691	6·758	6·827	6·897	6·968	7·041				
82	7·115	7·191	7·269	7·348	7·429	7·511	7·596	7·682	7·770	7·861	7·953	8·048				
83	8·144	8·243	8·345	8·449	8·556	8·665	8·777	8·892	9·010	9·131	9·255	9·383				
84	9·514	9·649	9·788	9·931	10·08	10·23	10·39	10·55	10·71	10·88	11·06	11·24	Difference columns cease to be useful.			
85	11·43	11·62	11·83	12·03	12·25	12·47	12·71	12·95	13·20	13·46	13·73	14·01				
86	14·30	14·61	14·92	15·26	15·60	15·97	16·35	16·75	17·17	17·61	18·07	18·56				
87	19·08	19·63	20·21	20·82	21·47	22·16	22·90	23·69	24·54	25·45	26·43	27·49				
88	28·64	29·88	31·24	32·73	34·37	36·18	38·19	40·44	42·96	45·83	49·10	52·88				
89	57·29	62·50	68·75	76·39	85·94	98·22	114·6	137·5	171·9	229·2	343·8	687·5				

TABLE 6.

Table of Haversines.

(Calculated by the author from Log. Havs. in Inman's Nautical Tables.)

Note.—This table goes up to 180°, which is more than sufficient for all geographical calculations in connection with wireless telegraphy. However for other purposes, angles above 180° may be required, in which case the following will be of use.

If A = angle greater than 180°.

Hav. A = Hav. $(360 - A)$ which is given in the Table.

Angle.		Haversine.	Difference.	Angle.		Haversine.	Difference.	Angle.		Haversine.	Difference.	Angle.		Haversine.	Difference.
°	′			°	′			°	′			°	′		
0	0	0·000000	·000019	14	30	0·0159	·0011	29	0	0·0626	·0022	43	30	0·1373	·0030
0	30	0·000019	·000057	15	0	0·0170	·0012	29	30	0·0648	·0022	44	0	0·1403	·0030
1	0	0·000076	·000095	15	30	0·0182	·0012	30	0	0·0670	·0022	44	30	0·1433	·0031
1	30	0·000171	·000134	16	0	0·0194	·0012	30	30	0·0692	·0022	45	0	0·1464	·0031
2	0	0·000305	·000172	16	30	0·0206	·0012	31	0	0·0714	·0022	45	30	0·1495	·0031
2	30	0·000476	·000209	17	0	0·0218	·0013	31	30	0·0736	·0023	46	0	0·1526	·0032
3	0	0·000685	·000248	17	30	0·0231	·0013	32	0	0·0759	·0023	46	30	0·1558	·0032
3	30	0·000933	·000285	18	0	0·0244	·0014	32	30	0·0782	·0024	47	0	0·1590	·0032
4	0	0·001218	·000323	18	30	0·0258	·0014	33	0	0·0806	·0024	47	30	0·1622	·0032
4	30	0·001541	·000362	19	0	0·0272	·0014	33	30	0·0830	·0024	48	0	0·1654	·0032
5	0	0·001903	·000399	19	30	0·0286	·0015	34	0	0·0854	·0025	48	30	0·1686	·0033
5	30	0·002302	·000437	20	0	0·0301	·0015	34	30	0·0879	·0025	49	0	0·1719	·0033
6	0	0·002739	·000475	20	30	0·0316	·0016	35	0	0·0904	·0025	49	30	0·1752	·0033
6	30	0·003214	·000513	21	0	0·0332	·0016	35	30	0·0929	·0025	50	0	0·1785	·0034
7	0	0·003727	·000550	21	30	0·0348	·0016	36	0	0·0954	·0026	50	30	0·1819	·0034
7	30	0·004277	·000589	22	0	0·0364	·0016	36	30	0·0980	·0026	51	0	0·1853	·0034
8	0	0·004866	·000626	22	30	0·0380	·0017	37	0	0·1006	·0027	51	30	0·1887	·0034
8	30	0·005492	·000664	23	0	0·0397	·0017	37	30	0·1033	·0027	52	0	0·1921	·0035
9	0	0·006156	·000701	23	30	0·0414	·0018	38	0	0·1060	·0027	52	30	0·1956	·0034
9	30	0·006857	·000739	24	0	0·0432	·0018	38	30	0·1087	·0027	53	0	0·1990	·0035
10	0	0·007596	·000777	24	30	0·0450	·0018	39	0	0·1114	·0028	53	30	0·2025	·0036
10	30	0·008373	·000813	25	0	0·0468	·0019	39	30	0·1142	·0028	54	0	0·2061	·0035
11	0	0·009186	·000852	25	30	0·0487	·0019	40	0	0·1170	·0028	54	30	0·2096	·0036
11	30	0·010038	·000888	26	0	0·0506	·0019	40	30	0·1198	·0028	55	0	0·2132	·0036
12	0	0·010926	·000926	26	30	0·0525	·0020	41	0	0·1226	·0029	55	30	0·2168	·0036
12	30	0·011852	·000963	27	0	0·0545	·0020	41	30	0·1255	·0029	56	0	0·2204	·0036
13	0	0·012815	·001000	27	30	0·0565	·0020	42	0	0·1284	·0029	56	30	0·2240	·0036
13	30	0·013815	·001037	28	0	0·0585	·0020	42	30	0·1313	·0030	57	0	0·2276	·0037
14	0	0·014852	·001074	28	30	0·0605	·0021	43	0	0·1343	·0030	57	30	0·2313	·0037
14	30	0·015926		29	0	0·0626		43	30	0·1373		58	0	0·2350	

Angle. °	′	Haversine.	Difference.	Angle. °	′	Haversine.	Difference.	Angle. °	′	Haversine.	Difference.	Angle. °	′	Haversine.	Difference.
58	0	0·2350	·0037	77	30	0·3917	·0043	104	0	0·6210	·0084	142	0	0·8939	·0053
58	30	0·2387	·0038	78	0	0·3960	·0043	105	0	0·6294	·0084	143	0	0·8992	·0052
59	0	0·2425	·0037	78	30	0·4003	·0043	106	0	0·6378	·0084	144	0	0·9044	·0052
59	30	0·2462	·0038	79	0	0·4046	·0043	107	0	0·6462	·0083	145	0	0·9096	·0051
60	0	0·2500	·0038	79	30	0·4089	·0043	108	0	0·6545	·0083	146	0	0·9147	·0050
60	30	0·2538	·0038	80	0	0·4132	·0043	109	0	0·6628	·0082	147	0	0·9197	·0049
61	0	0·2576	·0038	80	30	0·4175	·0043	110	0	0·6710	·0082	148	0	0·9246	·0048
61	30	0·2614	·0038	81	0	0·4218	·0043	111	0	0·6792	·0081	149	0	0·9294	·0045
62	0	0·2652	·0039	81	30	0·4261	·0043	112	0	0·6873	·0081	150	0	0·9329	·0044
62	30	0·2691	·0039	82	0	0·4304	·0043	113	0	0·6954	·0080	151	0	0·9373	·0042
63	0	0·2730	·0039	82	30	0·4347	·0043	114	0	0·7034	·0080	152	0	0·9415	·0040
63	30	0·2769	·0039	83	0	0·4390	·0044	115	0	0·7114	·0079	153	0	0·9455	·0039
64	0	0·2808	·0039	83	30	0·4434	·0043	116	0	0·7193	·0078	154	0	0·9494	·0038
64	30	0·2847	·0040	84	0	0·4477	·0044	117	0	0·7271	·0077	155	0	0·9532	·0036
65	0	0·2887	·0039	84	30	0·4521	·0043	118	0	0·7348	·0076	156	0	0·9568	·0035
65	30	0·2926	·0040	85	0	0·4564	·0043	119	0	0·7424	·0076	157	0	0·9603	·0034
66	0	0·2966	·0040	85	30	0·4607	·0044	120	0	0·7500	·0075	158	0	0·9637	·0032
66	30	0·3006	·0040	86	0	0·4651	·0043	121	0	0·7575	·0074	159	0	0·9669	·0030
67	0	0·3046	·0040	86	30	0·4694	·0044	122	0	0·7649	·0074	160	0	0·9699	·0029
67	30	0·3086	·0041	87	0	0·4738	·0044	123	0	0·7723	·0073	161	0	0·9728	·0027
68	0	0·3127	·0040	87	30	0·4782	·0043	124	0	0·7796	·0072	162	0	0·9755	·0026
68	30	0·3167	·0041	88	0	0·4825	·0044	125	0	0·7868	·0071	163	0	0·9781	·0025
69	0	0·3208	·0041	88	30	0·4869	·0043	126	0	0·7939	·0070	164	0	0·9806	·0024
69	30	0·3249	·0040	89	0	0·4912	·0044	127	0	0·8009	·0070	165	0	0·9830	·0023
70	0	0·3289	·0041	89	30	0·4956	·0044	128	0	0·8079	·0068	166	0	0·9853	·0021
70	30	0·3330	·0042	90	0	0·5000	·0087	129	0	0·8147	·0067	167	0	0·9874	·0019
71	0	0·3372	·0041	91	0	0·5087	·0088	130	0	0·8214	·0066	168	0	0·9893	·0016
71	30	0·3413	·0041	92	0	0·5175	·0087	131	0	0·8280	·0066	169	0	0·9909	·0015
72	0	0·3454	·0042	93	0	0·5262	·0087	132	0	0·8346	·0064	170	0	0·9924	·0014
72	30	0·3496	·0042	94	0	0·5349	·0087	133	0	0·8410	·0063	171	0	0·9938	·0013
73	0	0·3538	·0042	95	0	0·5436	·0087	134	0	0·8473	·0063	172	0	0·9951	·0011
73	30	0·3580	·0042	96	0	0·5523	·0087	135	0	0·8536	·0062	173	0	0·9962	·0010
74	0	0·3622	·0042	97	0	0·5610	·0086	136	0	0·8598	·0060	174	0	0·9972	·0009
74	30	0·3664	·0042	98	0	0·5696	·0086	137	0	0·8658	·0059	175	0	0·9981	·0007
75	0	0·3706	·0042	99	0	0·5782	·0086	138	0	0·8717	·0057	176	0	0·9988	·0005
75	30	0·3748	·0042	100	0	0·5868	·0086	139	0	0·8774	·0056	177	0	0·9993	·0004
76	0	0·3790	·0043	101	0	0·5954	·0086	140	0	0·8830	·0055	178	0	0·9997	·0002
76	30	0·3833	·0042	102	0	0·6040	·0085	141	0	0·8885	·0054	179	0	0·9999	·0001
77	0	0·3875	·0042	103	0	0·6125	·0085	142	0	0·8939		180	0	1·0000	
77	30	0·3917		104	0	0·6210									

TABLES 7 AND 8.

TABLE OF FUNCTIONS E AND B, USED IN CALCULATING AERIAL CAPACITIES BY PROF. HOWE'S FORMULA (PARAGRAPH 5).

TABLE 7.

$\frac{l}{2h}$	E
0·5	0·48
0·6	0·56
0·7	0·67
0·8	0·75
0·9	0·84
1·0	0·94
1·25	1·12
1·50	1·30
1·75	1·48
2·00	1·64
2·5	1·93
3·0	2·19
3·5	2·42
4·0	2·62
4·5	2·81
5·0	2·98
6·0	3·28
7·0	3·56
8·0	3·78
9·0	4·00
10·0	4·20
11·0	4·37
12·0	4·53
13·0	4·68
14·0	4·81
15·0	4·94
16·0	5·06
17.0	5·17
18·0	5·27
19·0	5·37
20·0	5·46

TABLE 8.

M	B
2	0
3	0·46
4	1·24
5	2·26
6	3·48
7	4·85
8	6·40
9	8·06
10	9·80
11	11·65
12	13·58

Prof. Howe, "Capacity of Radio Telegraphic Antennæ," *Wireless World*, with interpolation additions by the author.

TABLE 9.

TABLE OF FUNCTION Q FOR USE IN LORENZ'S EQUATION $L_s = an^2Q$ CMS. (PARAGRAPH 7).

Data taken from Table IV., Vol. VIII., No. 1, of *Bull. Bureau of Standards*, with interpolations by the author. Values of $\frac{2a}{b}$ and Q are given over a range for which the formula gives accurate results.

$\frac{2a}{b}$	Q	$\frac{2a}{b}$	Q	$\frac{2a}{b}$	Q	$\frac{2a}{b}$	Q
0·20	3·632	0·90	12·631	1·60	18·304	2·30	22·324
0·21	3·797	0·91	12·729	1·61	18·373	2·31	22·374
0·22	3·961	0·92	12·828	1·62	18·442	2·32	22·423
0·23	4·125	0·93	12·924	1·63	18·501	2·33	22·473
0·24	4·289	0·94	13·021	1·64	18·578	2·34	22·522
0·25	4·452	0·95	13·116	1·65	18·645	2·35	22·571
0·26	4·614	0·96	13·212	1·66	18·711	2·36	22·620
0·27	4·773	0·97	13·306	1·67	18·777	2·37	22·669
0·28	4·929	0·98	13·401	1·68	18·842	2·38	22·718
0·29	5·082	0·99	13·495	1·69	18·906	2·39	22·767
0·30	5·234	1·00	13·589	1·70	18·969	2·40	22·815
0·31	5·385	1·01	13·682	1·71	19·032	2·41	22·863
0·32	5·535	1·02	13·775	1·72	19·094	2·42	22·911
0·33	5·684	1·03	13·877	1·73	19·156	2·43	22·958
0·34	5·832	1·04	13·959	1·74	19·218	2·44	23·006
0·35	5·980	1·05	14·049	1·75	19·279	2·45	23·053
0·36	6·127	1·06	14·140	1·76	19·339	2·46	23·101
0·37	6·274	1·07	14·230	1·77	19·399	2·47	23·148
0·38	6·420	1·08	14·319	1·78	19·459	2·48	23·195
0·39	6·564	1·09	14·407	1·79	19·519	2·49	23·242
0·40	6·710	1·10	14·496	1·80	19·579	2·50	23·288
0·41	6·852	1·11	14·583	1·81	19·639	2·51	23·335
0·42	6·995	1·12	14·671	1·82	19·699	2·52	23·380
0·43	7·135	1·13	14·757	1·83	19·758	2·53	23·426
0·44	7·273	1·14	14·843	1·84	19·818	2·54	23·471
0·45	7·409	1·15	14·927	1·85	19·877	2·55	23·516
0·46	7·544	1·16	15·012	1·86	19·936	2·56	23·561
0·47	7·678	1·17	15·094	1·87	19·995	2·57	23·606
0·48	7·811	1·18	15·177	1·88	20·054	2·58	23·651
0·49	7·943	1·19	15·258	1·89	20·113	2·59	23·696
0·50	8·075	1·20	15·338	1·90	20·174	2·60	23·740
0·51	8·205	1·21	15·418	1·91	20·233	2·61	23·784
0·52	8·335	1·22	15·498	1·92	20·289	2·62	23·828
0·53	8·464	1·23	15·578	1·93	20·347	2·63	23·872
0·54	8·593	1·24	15·657	1·94	20·405	2·64	23·916
0·55	8·721	1·25	15·736	1·95	20·463	2·65	23·960
0·56	8·848	1·26	15·815	1·96	20·520	2·66	24·004
0·57	8·974	1·27	15·894	1·97	20·577	2·67	24·048
0·58	9·098	1·28	15·972	1·98	20·634	2·68	24·091
0·59	9·219	1·29	16·050	1·99	20·690	2·69	24·135
0·60	9·339	1·30	16·128	2·00	20·746	2·70	24·178
0·61	9·460	1·31	16·205	2·01	20·802	2·71	24·221
0·62	9·581	1·32	16·283	2·02	20·858	2·72	24·265
0·63	9·701	1·33	16·360	2·03	20·914	2·73	24·308
0·64	9·820	1·34	16·437	2·04	20·969	2·74	24·351
0·65	9·938	1·35	16·514	2·05	21·024	2·75	24·393
0·66	10·056	1·36	16·591	2·06	21·079	2·76	24·436
0·67	10·173	1·37	16·668	2·07	21·134	2·77	24·478
0·68	10·289	1·38	16·745	2·08	21·189	2·78	24·521
0·69	10·403	1·39	16·821	2·09	21·243	2·79	24·563
0·70	10·514	1·40	16·898	2·10	21·298	2·80	24·605
0·71	10·625	1·41	16·973	2·11	21·352	2·81	24·647
0·72	10·736	1·42	17·048	2·12	21·405	2·82	24·689
0·73	10·846	1·43	17·122	2·13	21·457	2·83	24·731
0·74	10·956	1·44	17·196	2·14	21·510	2·84	24·772
0·75	11·065	1·45	17·269	2·15	21·562	2·85	24·813
0·76	11·175	1·46	17·342	2·16	21·614	2·86	24·854
0·77	11·284	1·47	17·414	2·17	21·666	2·87	24·895
0·78	11·393	1·48	17·485	2·18	21·718	2·88	24·936
0·79	11·503	1·49	17·555	2·19	21·769	2·89	24·976
0·80	11·608	1·50	17·624	2·20	21·820	2·90	25·017
0·81	11·712	1·51	17·693	2·21	21·871	2·91	25·057
0·82	11·816	1·52	17·761	2·22	21·922	2·92	25·098
0·83	11·919	1·53	17·829	2·23	21·973	2·93	25·138
0·84	12·023	1·54	17·897	2·24	22·023	2·94	25·179
0·85	12·126	1·55	17·965	2·25	22·074	2·95	25·219
0·86	12·229	1·56	18·033	2·26	22·124	2·96	25·259
0·87	12·331	1·57	18·101	2·27	22·174	2·97	25·298
0·88	12·433	1·58	18·169	2·28	22·224	2·98	25·338
0·89	12·532	1·59	18·237	2·29	22·274	2·99	25·372
						3·00	25·416

TABLE 10.

TABLE OF FUNCTION X FOR USE IN RAYLEIGH'S EQUATION $L_s = 4\pi a n^2 X$ CMS.

(PARAGRAPH 7) WHERE $X = \left[\log_e \frac{8a}{b} - \frac{1}{2} + \frac{b^2}{32a^2} \left(\log_e \frac{8a}{b} + 0{\cdot}25 \right) \right]$.

Table compiled by the author, for $\frac{a}{b}$ over a range which the formula gives accurate results.

$\frac{a}{b}$	Function X	$\frac{a}{b}$	Function X	$\frac{a}{b}$	Function X	$\frac{a}{b}$	Function X
1·00	1·653	5·60	3·308	10·20	3·906	26·0	4·831
1·10	1·738	5·70	3·326	10·30	3·916	26·5	4·851
1·20	1·817	5·80	3·344	10·40	3·926	27·0	4·870
1·30	1·891	5·90	3·361	10·50	3·936	27·5	4·889
1·40	1·960	6·00	3·378	10·60	3·946	28·0	4·908
1·50	2·027	6·10	3·395	10·70	3·956	28·5	4·927
1·60	2·090	6·20	3·412	10·80	3·966	29·0	4·946
1·70	2·148	6·30	3·428	10·90	3·975	29·5	4·964
1·80	2·202	6·40	3·444	11·00	3·984	30·0	4·982
1·90	2·250	6·50	3·460	11·10	3·993	30·5	4·999
2·00	2·296	6·60	3·475	11·20	4·002	31·0	5·016
2·10	2·340	6·70	3·490	11·30	4·011	31·5	5·033
2·20	2·383	6·80	3·505	11·40	4·019	32·0	5·050
2·30	2·425	6·90	3·519	11·50	4·027	32·5	5·066
2·40	2·466	7·00	3·533	11·60	4·035	33·0	5·082
2·50	2·514	7·10	3·547	11·70	4·043	33·5	5·098
2·60	2·551	7·20	3·561	11·80	4·051	34·0	5·114
2·70	2·586	7·30	3·574	11·90	4·059	34·5	5·129
2·80	2·620	7·40	3·587	12·00	4·067	35·0	5·144
2·90	2·652	7·50	3·600	12·5	4·107	35·5	5·159
3·00	2·683	7·60	3·613	13·0	4·145	36·0	5·173
3·10	2·715	7·70	3·626	13·5	4·183	36·5	5·187
3·20	2·747	7·80	3·639	14·0	4·220	37·0	5·201
3·30	2·779	7·90	3·651	14·5	4·256	37·5	5·215
3·40	2·810	8·00	3·662	15·0	4·290	38·0	5·228
3·50	2·841	8·10	3·674	15·5	4·323	38·5	5·241
3·60	2·871	8·20	3·686	16·0	4·355	39·0	5·253
3·70	2·899	8·30	3·698	16·5	4·386	39·5	5·265
3·80	2·925	8·40	3·710	17·0	4·416	40·0	5·277
3·90	2·950	8·50	3·722	17·5	4·445	41·0	5·300
4·00	2·974	8·60	3·733	18·0	4·474	42·0	5·323
4·10	2·998	8·70	3·744	18·5	4·501	43·0	5·346
4·20	3·022	8·80	3·755	19·0	4·527	44·0	5·368
4·30	3·045	8·90	3·766	19·5	4·552	45·0	5·390
4·40	3·067	9·00	3·777	20·0	4·576	46·0	5·411
4·50	3·089	9·10	3·788	20·5	4·599	47·0	5·432
4·60	3·111	9·20	3·799	21·0	4·622	48·0	5·452
4·70	3·132	9·30	3·810	21·5	4·644	49·0	5·472
4·80	3·153	9·40	3·821	22·0	4·666	50·0	5·492
4·90	3·173	9·50	3·832	22·5	4·688	51·0	5·512
5·00	3·193	9·60	3·843	23·0	4·709	52·0	5·531
5·10	3·213	9·70	3·853	23·5	4·730	53·0	5·550
5·20	3·233	9·80	3·864	24·0	4·751	54·0	5·569
5·30	3·252	9·90	3·875	24·5	4·771	55·0	5·587
5·40	3·271	10·00	3·886	25·0	4·791		
5·50	3·290	10·10	3·896	25·5	4·811		

TABLES 11 AND 12.

Table of Correction Functions A and B for Use in Correction Formula.

$$\Delta L = 4\pi a n\,(A + B) \text{ (Paragraph 7).}$$

Table of A from Table VII., Vol. VIII., No. 1, *Bull. Bureau of Standards*, with additions by the author.

Table of B from Table VIII., Vol. VIII., No. 1, *Bull. Bureau of Standards*, with additions by the author.

TABLE 11.—Corrections for Insulation.

Note.—For $\frac{d}{D}$ over 0·58 A is positive. For $\frac{d}{D}$ less than 0·57 A is negative.

$\frac{d}{D}$	A	$\frac{d}{D}$	A	$\frac{d}{D}$	A	$\frac{d}{D}$	A
1·00	+0·5568	0·75	0·2691	0·50	0·1363	0·25	0·8294
0·99	0·5470	0·74	0·2556	0·49	0·1558	0·24	0·8699
0·98	0·5370	0·73	0·2419	0·48	0·1758	0·23	0·9121
0·97	0·5268	0·72	0·2282	0·47	0·1966	0·22	0·9566
0·96	0·5163	0·71	0·2143	0·46	0·2183	0·21	1·0035
0·95	0·5055	0·70	0·2001	0·45	0·2406	0·20	1·0526
0·94	0.4947	0·69	0·1857	0·44	0·2632	0·19	1·1046
0·93	0·4839	0·68	0·1710	0·43	0·2864	0·18	1·1601
0·92	0·4731	0·67	0·1560	0·42	0·3102	0·17	1·2179
0·91	0·4623	0·66	0·1410	0·41	0·3347	0·16	1·2777
0·90	0·4515	0·65	0·1261	0·40	0·3594	0·15	1·3402
0·89	0·4404	0·64	0·1105	0·39	0·3846	0·14	1·4082
0·88	0·4292	0·63	0·0947	0·38	0·4106	0·13	1·4822
0·87	0·4178	0·62	0·0787	0·37	0·4374	0·12	1·5627
0·86	0·4063	0·61	0·0625	0·36	0·4647	0·11	1·6510
0·85	0·3945	0·60	+0·0460	0·35	0·4929	0·10	1·7451
0·84	0·3826	0·59	+0·0293	0·34	0·5219	0·09	1·8470
0·83	0·3706	0·58	+0·0123	0·33	0·5521	0·08	1·9642
0·82	0·3585	0·57	−0·0048	0·32	0·5831	0·07	2·0971
0·81	0·3463	0·56	−0·0226	0·31	0·6148	0·06	2·2550
0·80	0·3337	0·55	0·0410	0·30	0·6471	0·05	2·4389
0·79	0·3210	0·54	0·0597	0·29	0·6806	0·04	2·6952
0·78	0·3082	0·53	0·0787	0·28	0·7154	0·03	3·0250
0·77	0·2954	0·52	0·0980	0·27	0·7519	0·02	3·4620
0·76	0·2824	0·51	0·1173	0·26	0·7896	0·01	4·0483

TABLE 12.—Corrections for the Number of Turns.

Note.—All positive.

n	B	n	B	n	B	n	B
1	0·0000	31	0·3091	61	0·3219	91	0·3271
2	0·1137	32	0·3099	62	0·3222	92	0·3272
3	0·1663	33	0·3106	63	0·3224	93	0·3273
4	0·1973	34	0·3113	64	0·3227	94	0·3274
5	0·2180	35	0·3119	65	0·3229	95	0·3275
6	0·2329	36	0·3125	66	0·3231	96	0·3276
7	0·2443	37	0·3131	67	0·3233	97	0·3277
8	0·2532	38	0·3137	68	0·3235	98	0·3278
9	0·2604	39	0·3143	69	0·3237	99	0·3279
10	0·2664	40	0·3148	70	0·3239	100	0·3280
11	0·2710	41	0·3153	71	0·3241	105	0·3284
12	0·2753	42	0·3157	72	0·3243	110	0·3288
13	0·2791	43	0·3161	73	0·3245	115	0·3292
14	0·2826	44	0·3165	74	0·3247	120	0·3295
15	0·2857	45	0·3169	75	0·3249	130	0·3301
16	0·2885	46	0·3173	76	0·3251	140	0·3307
17	0·2910	47	0·3177	77	0·3252	150	0·3311
18	0·2933	48	0·3180	78	0·3253	160	0·3315
19	0·2955	49	0·3183	79	0·3255	170	0·3319
20	0·2974	50	0·3186	80	0·3257	180	0·3323
21	0·2990	51	0·3189	81	0·3259	190	0·3326
22	0·3005	52	0·3192	82	0·3261	200	0·3328
23	0·3020	53	0·3195	83	0·3263	250	0·3336
24	0·3031	54	0·3198	84	0·3264	300	0·3343
25	0·3042	55	0·3201	85	0·3265	400	0·3351
26	0·3053	56	0·3204	86	0·3266	500	0·3356
27	0·3062	57	0·3207	87	0·3267	600	0·3359
28	0·3070	58	0·3210	88	0·3268	700	0·3361
29	0·3077	59	0·3213	89	0·3269	800	0·3363
30	0·3083	60	0·3216	90	0·3270	900	0·3364
						1000	0·3365

TABLE 13.

Table of Constants for Stefan's Formula for "Pancake" or Toroidal Coils.

Table VI. in *Bull. Bureau of Standards*, Wash.

$\frac{b}{c}$ or $\frac{c}{b}$	y_1	y_2	$\frac{b}{c}$ or $\frac{c}{b}$	y_1	y_2
0·00	0·50000	0·1250	0·55	0·80815	0·3437
0·05	0·54899	0·1269	0·60	0·81823	0·3839
0·10	0·59243	0·1325	0·65	0·82648	0 4274
0·15	0·63102	0·1418	0·70	0·83311	0·4739
0·20	0·66520	0·1548	0 75	0·83831	0·5234
0·25	0·69532	0·1714	0·80	0·84225	0·5760
0·30	0·72172	0·1916	0·85	0·84509	0·6317
0·35	0 74469	0·2152	0·90	0·84697	0·6902
0·40	0·76454	0·2423	0·95	0·84801	0·7518
0·45	0·78154	0·2728	1·00	0 84834	0 8162
0·50	0·79600	0·3066			

Data for this Table obtained from outline figures given by Rosa, p. 141, Vol. VIII., No. 1, of *Bull. Bureau of Standards*, with interpolations by the author.

n = *Turns*	E_1	n = *Turns*	E_1
2	0·00653	9	0·01258
3	0 00905	10	0·01276
4	0·01035	12	0·01302
5	0 01105	14	0 01323
6	0·01160	16	0·01339
7	0 01203	18	0·01349
8	0·01236	20	0·01357
		∞	0·01806

TABLE 14.

Table of Function γ for use in Mutual Inductance Formula (Paragraph 8).

Table due to W. H. Nottage, B.Sc., *Wireless World*, 1915, p. 526.

$\frac{r_2}{r_1}$.	γ.	$\frac{r_2}{r_1}$.	γ.
0·01	50·3	0·28	9·58
0·02	41·5	0·30	8·84
0·03	36·3	0·34	7·56
0·04	32·8	0·38	6·46
0 05	30·0	0·40	5·97
0·06	27·7	0·45	4·89
0·07	25·8	0·50	3·97
0·08	24·2	0·55	3·19
0·09	22·8	0·60	2·53
0·10	21·5	0·65	1·96
0·12	19·3	0·70	1·48
0·14	17·4	0·75	1·075
0·16	15·9	0·80	0·735
0·18	14·5	0·85	0·456
0·20	13·3	0·90	0·239
0·22	12·2	0·95	0·082
0 24	11·2	1·00	0·000
0·26	10·4	—	

TABLE 15.—STRANDED CONDUCTORS.

The figures in this Table apply to situations where the maximum temperature of the air does not exceed 100° F. (37·7° C.). A margin in the maximum possible temperature of the cables has been allowed to provide for contingencies. The figures in columns 3, 3a, 4, and 4a have been supplied by the National Physical Laboratory to comply with Rule 36.

Gauge.	Section.	Rubber insulated cables.		Paper or fibre insulated cables.		Minimum insulation resistance of one mile in megohms at 60° F.			Resistance.	Minimum radial thickness.				Gauge.
		Current.	Voltsdrop.	Current.	Volts drop.	Vulcanised rubber.		Paper or fibre.		Vulcanised rubber.		Paper or fibre.	Lead sheath.	
Number of wires and gauge in S.W.G or inches.	Nominal sectional area of conductors.	Maximum current permissible.	Approximate total length in circuit (lead and return) for 1-volt drop (Col. 3).	Maximum current permissible.	Approximate total length in circuit (lead and return) for 1-volt drop (Col. 4).	Up to 250 volts.	Up to 650 volts.	(Class B.)	Conductor resistance in standard ohms per 1,000 yards.	Up to 250 volts.	Up to 650 volts.	Class B).		Number of wires and gauge in S.W.G. or inches.
1.	2.	3.*	3a.	4.*	4a.	5.	6.	7.	8.	9.	10.	11.	12.	13.
	Sq. inches.	Amps.	Yards.	Amps.	Yards.	Megohms.	Megohms.	Megohms.	Ohms.	Inches.	Inches.	Inches.	Inches.	
Fittings Wires. 3/25	0·0009	3·7	10	3·7	10	1,250	4,500	For conductors smaller than 7/18, the insulation resistance must not be less than 140 megohms.	26·01	0·034	0·062	—	—	3/25
Fittings Wires. 3/24	0·0011	4·5	10	4·5	10	1,250	4,500		21·50	0·034	0·062	—	—	3/24
Fittings Wires. 3/23	0·0013	5·3	10	5·3	10	1,250	4,500		18·07	0·035	0·062	—	—	3/23
1/18	0·0018	7·2	10	0·2	10	2,000	5,000		13·29	0·035	0·062	—	—	1/18
3/22	0·0018	7·2	10	7·2	10	1,250	4,500		13·27	0·036	0·062	—	—	3/22
7/25	0·0022	8·6	10	8·6	10	1,250	4,500		11·12	0·036	0·062	—	—	7/25
3/21	0·0024	9·5	10	9·5	10	1,250	4,500		10·16	0·038	0·062	—	—	3/21
1/17	0·0025	9·8	10	9·8	10	2,000	5,000		9·761	0·036	0·062	—	—	1/17
7/24	0·0026	10·4	10	10·4	10	1,250	4,500		9·19	0·037	0·062	—	—	7/24
3/20	0·0030	12·0	10	12·0	10	1,250	4,500		8·0	0·038	0·062	—	—	3/20
7/23	0·0031	12·4	10	12·4	10	1,250	4,500		7·72	0·037	0·062	—	—	7/23
1/16	0·0032	12·9	10	12·9	10	2,000	5,000		7·47	0·036	0·062	—	—	1/16
3/19	0·0037	14·8	10	14·8	10	1,250	4,500		6·504	0·039	0·062	—	—	3/19
1/15	0·0041	16·3	10	16·3	10	1,250	4,500		5·905	0·037	0·062	—	—	1/15
7/22	0·0042	17·0	10	17·0	10	1,250	4,500		5·672	0·038	0·062	—	—	7/22
1/14	0·0050	19·0	10	20·1	10	1,250	4,500		4·783	0·038	0·062	—	—	1/14
3/18	0·0053	20·0	11	21·2	10	1,250	4,500		4·516	0·040	0·062	—	—	3/18
7/21	0·0055	21·0	11	22·1	10	1,250	4,500		4·343	0·040	0·062	—	—	7/21
7/20	0·0070	24·0	12	28·0	10	900	4,000		3·431	0·041	0·062	—	—	7/20
7/19	0·0086	28·0	12	34·6	10	900	4,000		2·779	0·042	0·062	—	—	7/19
7/18	0·0125	34·0	14	50·0	10	900	4,000	140	1·930	0·044	0·062	0·080	0·060	7/18

7/17	0·017	40·0	17	67·0	10	900	4,000	140	1·418	0·047	0·062	0·080	0·060	7/17
19/20	0·019	43·0	18	69·0	11	750	3,500	140	1·266	0·048	0·062	0·080	0·060	19/20
7/16	0·022	46·0	19	75·0	11	900	3,500	140	1·086	0·049	0·062	0·080	0·060	7/16
19/19	0·023	47·0	19	76·0	12	750	3,500	140	1·0260	0·050	0·062	0·080	0·060	19/19
7/·068"	0·025	50·0	20	81·0	12	750	3,500	140	0·9618	0·050	0·062	0·080	0·060	7/·068"
7/15	0·028	53·0	21	86·0	12	750	3,500	140	0·8578	0·052	0·062	0·080	0·060	7/15
19/18	0·034	59·0	23	96·0	13	750	3,000	120	0·7125	0·054	0·062	0·080	0·060	19/18
7/14	0·035	60·0	23	97·0	13	750	3,500	120	0·6949	0·054	0·062	0·080	0·060	7/14
19/17	0·046	70·0	26	114·0	15	750	3,000	120	0·5234	0·058	0·062	0·080	0·060	19/17
7/·097"	0·050	74·0	27	120·0	16	750	3,500	120	0·4727	0·059	0·062	0·080	0·060	7/·097"
19/·058"	0·050	74·0	27	120·0	16	750	3,000	120	0·4880	0·059	0·062	0·080	0·060	19/·058"
19/16	0·060	83·0	29	135·0	17	750	3,000	110	0.4007	0·062	0·066	0·080	0·070	19/16
19/·072"	0·075	97·0	31	157·0	18	600	3,000	110	0·3167	0·060	0·066	0·080	0·070	19/·072"
19/14	0·094	113·0	33	183·0	19	600	3,000	100	0·2565	0·070	0·071	0·090	0·070	19/14
19/·083"	0·100	118·0	34	191·0	20	600	3,000	100	0·2383	0·071	0·071	0·090	0·070	19/·083"
37/16	0·117	130·0	36	210·0	21	600	3,000	90	0·2059	0·075	0·076	0·090	0·070	37/16
19/·092"	0·125	134·0	37	219·0	21	600	3,000	90	0·1940	0·076	0·076	0·090	0·070	19/·092"
37/·072"	0·150	152·0	39	246·0	23	600	3,000	90	0·1627	0·080	0·080	0·090	0·080	37/·072"
19/·101"	0·150	152·0	39	246·0	23	600	3,000	90	0·1610	0·081	0·080	0·090	0·080	19/·101"
37/14	0·182	172·0	42	275·0	24	600	2,500	90	0·1318	0·086	0·087	0·090	0·080	37/14
37/·083"	0·200	184·0	43	296·0	25	600	2,500	90	0·1224	0·087	0·087	0·090	0·080	37/·083"
37/·092"	0·250	214·0	47	343·0	27	600	2,500	80	0·0997	0·094	0·094	0·100	0·090	37/·092"
37/·104"	0·300	240·0	50	385·0	29	600	2,500	80	0·0780	0·103	0·101	0·100	0·090	37/·104"
37/·112"	0·350	264·0	53	425·0	31	600	2,500	80	0·0672	0·107	0·107	0·100	0·090	37/·112"
61/·092"	0·400	288·0	55	464·0	32	600	2,500	80	0·0605	0·113	0·113	0·100	0·100	61/·092"
61/·097"	0·450	310·0	58	502·0	34	600	2,500	80	0·0544	0·121	0·118	0·100	0·100	61/·097"
61/·104"	0·500	332·0	60	540·0	35	600	2,500	80	0·0473	0·121	0·121	0·100	0·100	61/·104"
61/·108"	0·550	357·0	61	583·0	36	600	2,500	80	0·0439	0·125	0·125	0·110	0·110	61/·108"
61/·112"	0·600	384·0	62	624·0	36	600	2,500	80	0·0408	0·125	0·125	0·110	0·110	61/·112"
61/·118"	0·650	410·0	63	662·0	37	600	2,500	80	0·0368	0·129	0·129	0·110	0·110	61/·118"
91/·098"	0·700	434·0	64	700·0	38	600	2,500	70	0·0357	0·129	0·129	0·110	0·110	91/·098"
91/·101"	0·750	461·0	65	738·0	38	600	2,500	70	0·0336	0·131	0·131	0·110	0·110	91/·101"
91/·108"	0·800	488·0	65	776·0	39	600	2,500	70	0·0294	0·133	0·133	0·120	0·120	91/·108"
91/·112"	0·900	540·0	66	855·0	39	600	2,500	70	0·0273	0·137	0·137	0·120	0·120	91/·112"
91/·118"	1·000	595·0	67	932·0	40	600	2,500	70	0·0246	0·141	0·141	0·130	0·120	91/·118"
127/·101"	1·000	595·0	67	932·0	40	600	2,500	70	0·0241	0·141	0·141	0·130	0·120	127/·101"

* N.B.—It must not be assumed that this current is always permissible, especially for lighting circuits where the determining factor is the drop in volts.

TABLE 15A.—SINGLE STRAND CONDUCTORS.

COPPER ANNEALED. E.S.C. STANDARD.

By kind permission of Messrs. The London Electric Wire Co., Ltd.

Size.	Diameter.		Sectional area.		Weight.		Resistance at 60° F.		Current rating.	
					Pounds.		Standard ohms.		Ampères @	
S.W.G.	Inch.	M/m.	Square inch.	Square m/m.	Per 1,000 yards.	Per mile.	Per 1,000 yards.	Per mile.	1,000 per sq. inch.	I.E.E.
50	·0010	·02539	·0000007854	·0005067	·009081	·01598	30609	53872	·0007	This Column is compiled according to the Standards fixed by the Institution of Electrical Engineers.
49	·0012	·03048	·000001131	·0007296	·01308	·02302	21256	37411	·0011	
48	·0016	·04064	·000002011	·0012972	·02325	·04092	11957	21044	·0020	
47	·0020	·0508	·0000031	·002027	·03632	·06393	7652	13468	·0031	
46	·0024	·0610	·0000045	·002919	·05231	·09206	5314	9353	·0045	
45	·0028	·0711	·0000062	·003973	·07120	·1253	3904	6871	·0062	
44	·0032	·0813	·0000080	·005188	·09299	·1637	2989	5261	·0080	
43	·0036	·0914	·0000102	·006567	·1177	·2071	2362	4157	·0102	
42	·0040	·1016	·0000126	·008109	·1453	·2557	1913	3367	·0126	
41	·0044	·1118	·0000152	·009810	·1758	·3094	1581	2783	·0152	
40	·0048	·1219	·0000181	·011674	·2092	·3682	1329	2338	·0181	
39	·0052	·1321	·0000212	·013701	·2456	·4322	1132	1992	·0212	
38	·0060	·1524	·0000283	·018241	·3269	·5754	850·3	1496	·0283	
37	·0068	·1727	·0000363	·023430	·4199	·7390	662·0	1165	·0363	
36	·0076	·1930	·0000454	·029267	·5245	·9232	529·9	932·7	·0454	
35	·0084	·2134	·0000554	·035752	·6408	1·128	433·8	763·5	·0554	
34	·0092	·2337	·0000665	·042887	·7686	1·353	361·6	636·5	·0665	
33	·0100	·2539	·0000785	·050670	·9081	1·598	306·1	538·7	·0785	
32	·0108	·2743	·0000916	·059102	1·059	1·864	262·4	461·9	·0916	
31	·0116	·2946	·0001057	·068181	1·222	2·151	227·5	400·4	·1057	
30	·0124	·3149	·0001208	·077910	1·396	2·458	199·1	350·4	·1208	
29	·0136	·3454	·0001453	·093722	1·680	2·956	165·5	291·3	·1453	
28	·0148	·3759	·0001720	·11099	1·989	3·501	139·7	245·9	·1720	
27	·0164	·4166	·0002112	·13628	2·442	4·299	113·8	200·3	·2112	
26	·018	·4572	·0002545	·1642	2·942	5·178	94·47	166·3	·2545	
25	·020	·5080	·0003142	·2027	3·632	6·393	76·52	134·7	·3142	
24	·022	·5588	·0003801	·2453	4·395	7·736	63·24	111·3	·3801	
23	·024	·6096	·0004524	·2919	5·231	9·206	53·14	93·53	·452	
22	·028	·7112	·0006158	·3973	7·120	12·53	39·04	68·71	·616	2·5
21	·032	·8128	·0008042	·5188	9·299	16·37	29·89	52·61	·804	3·3
20	·036	·9144	·001018	·6567	11·77	20·71	23·62	41·57	1·018	4·0
19	·040	1·016	·001257	·8109	14·53	25·57	19·13	33·67	1·257	5·3
18	·048	1·219	·001810	1·168	20·92	36·82	13·29	23·38	1·810	7·2
17	·056	1·422	·002463	1·589	28·48	50·12	9·761	17·18	2·463	9·8
16	·064	1·626	·003217	2·075	37·20	65·47	7·473	13·15	3·217	12·9
15	·072	1·829	·004072	2·276	47·08	82·86	5·905	10·39	4·072	16·3
14	·080	2·032	·005027	3·243	58·12	102·3	4·783	8·418	5·027	19
13	·092	2·337	·006648	4·289	76·86	135·3	3·616	6·365	6·648	23
12	·104	2·642	·008495	5·480	98·22	172·9	2·830	4·981	8·495	28
11	·116	2·946	·01057	6·819	122·2	215·1	2·275	4·004	10·57	32
10	·128	3·251	·01287	8·304	148·8	261·9	1·868	3·288	12·87	35
9	·144	3·658	·01629	10·51	188·3	331·4	1·476	2·598	16·29	38
8	·160	4·064	·02011	12·97	232·5	409·2	1·196	2·104	20·11	44
7	·176	4·470	·02433	15·70	281·3	495·1	·9882	1·739	24·33	48
6	·192	4·877	·02895	18·68	334·8	589·2	·8303	1·461	28·95	53
5	·212	5·385	·03530	22·77	408·1	718·3	·6810	1·199	35·30	60
4	·232	5·893	·04227	27·27	488·8	860·3	·5687	1·001	42·27	65
3	·252	6·401	·04988	32·18	576·7	1015	·4820	·8483	49·88	74
2	·276	7·010	·05983	38·60	691·8	1218	·4018	·7072	59·83	83
1	·300	7·620	·07069	45·60	817·3	1438	·3401	·5986	70·69	92
1/0	·324	8·230	·08245	53·19	953·3	1678	·2916	·5132	82·45	102
2/0	·348	8·839	·0951	61·36	1100	1936	·2528	·4448	95·11	114
3/0	·372	9·449	·1087	70·13	1257	2212	·2212	·3893	108·7	123
4/0	·400	10·16	·1257	81·09	1453	2557	·1913	·3367	125·7	135
5/0	·432	10·97	·1466	94·56	1695	2983	·1640	·2887	146	150
6/0	·464	11·79	·1691	109·1	1955	3441	·1422	·2502	169	165
7/0	·500	12·70	·1963	126·6	2270	3996	·1224	·2155	196	178

TABLE 16.

“Eureka” Resistance Wire.

By kind permission of Messrs. The London Electric Wire Co., Ltd.

An Alloy, manufactured especially to give High Resistance with a Temperature Coefficient practically Nil.

Size.	Diameter.		Sectional area.		Weight.		Resistance at 60° F.		Current rating.	
					Pounds.		Standard ohms.		Ampères @	
S. W. G.	Inch.	M/m.	Square inch.	Square m/m.	Per 1000 yards.	Per mile.	Per 1000 yards.	Per mile.	1000 per sq. inch.	I.E.E.
44	·0032	·0813	·0000080	·005188	·0930	·1637	83664	147336	“Eureka”	
43	·0036	·0914	·0000102	·006567	·1177	·2072	66136	116396	was the first	
42	·0040	·1016	·0000126	·008109	·1453	·2558	53564	94276	Cupro Nickel	
41	·0044	·1118	·0000152	·009810	·1758	·3093	44268	77924	Alloy put on	
40	·0048	·1219	·0000181	·011674	·2093	·3683	37184	65464	the market.	
39	·0052	·1321	·0000212	·013701	·2451	·4314	31696	55776	It is prepared with great care	
38	·0060	·1524	·0000283	·018241	·3272	·5759	23808	41916	to secure a	
37	·0068	·1727	·0000363	·023430	·4197	·7387	18536	32620	non-corrodible	
36	·0076	·1930	·0000454	·029267	·5249	·9239	14840	26118	and stable	
35	·0084	·2134	·0000554	·035752	·6406	1·127	12149	21381	Alloy.	
34	·0092	·2337	·0000665	·042887	·7688	1·353	10128	17825		
33	·0100	·2540	·0000785	·050670	·9085	1·598	8571	15086		
32	·0108	·2743	·0000916	·059102	1·059	1·863	7350	12933	For well ventilated	
31	·0116	·2946	·000106	·068181	1·222	2·151	6370	11211	open spirals of	
30	·0124	·3149	·000121	·077910	1·399	2·462	5575	9811	“Eureka” Wire the figures given	
29	·0136	·3454	·000145	·093722	1·676	2·950	4634	8156	below will be found	
28	·0148	·3759	·000172	·11099	1·989	3·500	3914	6888	approximately	
27	·0164	·4166	·000211	·13628	2·440	4·294	3186	5608	correct.	
26	·018	·4572	·000254	·1642	2·942	5·180	2645	4656	Rise in	
25	·020	·5080	·000314	·2027	3·633	6·395	2142	3771	temperature.	
24	·022	·5588	·000380	·2453	4·392	7·730	1770	3116	100° F.	200° F.
23	·024	·6096	·000452	·2919	5·233	9·210	1487	2618	Amps.	Amps.
22	·028	·7112	·000616	·3973	7·120	12·53	1093	1924	1·09	1·9
21	·032	·8128	·000804	·5118	9·301	16·37	837·2	1473	1·3	2·3
20	·036	·9144	·001018	·6567	11·77	20·72	661·3	1164	1·6	2·8
19	·040	1·016	·001257	·8109	14·53	25·58	535·6	942·7	1·85	3·2
18	·048	1·219	·001810	1·168	20·93	36·83	371·8	654·6	2·4	4·3
17	·056	1·422	·002463	1·589	28·48	50·12	273·3	481·1	3·0	5·2
16	·064	1·626	·003217	2·075	37·20	65·47	209·4	368·5	3·7	6·6
15	·072	1·829	·004072	2·627	47·09	82·87	165·3	290·9	4·5	7·75
14	·080	2·032	·005027	3·243	58·13	102·3	133·9	235·7	5·25	9·25
13	·092	2·337	·006648	4·289	76·88	135·3	101·3	178·3	6·5	11·25
12	·104	2·642	·008495	5·480	98·24	172·9	79·3	139·5	7·75	13·75
11	·116	2·946	·01057	6·819	122·2	215·1	63·7	112·1	9·25	15·75
10	·128	3·251	·01287	8·303	148·8	261·9	52·3	92·0	10·6	18·75
9	·144	3·658	·01629	10·51	188·4	331·5	41·3	72·7	12·7	22·4
8	·160	4·064	·02011	12·97	232·5	409·2	33·5	58·9	14·8	26
7	·176	4·470	·02433	15·70	281·3	495·1	27·7	48·7	17·0	30
6	·192	4·877	·02895	18·68	334·7	589·1	23·3	40·9	19·5	34

TABLE 17.

ALUMINIUM WIRE.

(By kind permission of Messrs. The London Electric Wire Co., Ltd.)

Size.	Diameter.		Sectional Area.		Weight.		Resistance at 60° F.		Current Rating.
					Pounds.		Standard Ohms.		
S. W. G.	Inch.	M/m.	Square Inch.	Square M/m.	Per 1,000 Yards.	Per Mile.	Per 1,000 Yards.	Per Mile.	Amps. at 700 per sq. inch.
40	·0048	·1219	·0000181	·011674	·064	·112	2206	3882	
39	·0052	·1321	·0000212	·013701	·075	·132	1888	3320	
38	·0060	·1524	·0000283	·018241	·099	·175	1410	2480	
37	·0068	·1727	·0000363	·023430	·128	·225	1098	1934	
36	·0076	·1930	·0000454	·029267	·160	·282	876	1538	
35	·0084	·2134	·0000554	·035752	·195	·343	719	1268	
34	·0092	·2337	·0000665	·042887	·235	·413	599	1056	
33	·0100	·2540	·0000785	·050670	·277	·488	508	895.	
32	·0108	·2743	·0000916	·059102	·323	·568	435	766	
31	·0116	·2946	·0001057	·068181	·372	·655	378	666	
30	·0124	·3149	·0001208	·077910	·426	·751	331	583	
29	·0136	·3454	·0001453	·093722	·511	·899	276	485	
28	·0148	·3759	·0001720	·11099	·606	1·07	232	409	
27	·0164	·4166	·0002112	·13628	·743	1·31	189	332	
26	·018	·4572	·0002545	·1642	·895	1·58	157	277	
25	·020	·5080	·0003142	·2027	1·11	1·95	127	224	
24	·022	·5588	·0003801	·2453	1·34	2·36	105	185	·266
23	·024	·6096	·0004524	·2919	1·59	2·81	88	156	·317
22	·028	·7112	·0006158	·3973	2·17	3·82	65	114	·431
21	·032	·8128	·0008042	·5188	2·84	4·95	49·8	87·5	·563
20	·036	·9144	·001018	·6567	3·59	6·33	39·3	69·3	·714
19	·040	1·016	·001257	·8109	4·44	7·82	31·89	56·2	·882
18	·048	1·219	·001810	1·168	6·37	11·22	22·15	39·06	1·27
17	·056	1·422	·002463	1·589	8·67	15·23	16·26	28·64	1·72
16	·064	1·626	·003217	2·075	11·34	19·98	12·46	21·96	2·26
15	·072	1·829	·004072	2·627	14·34	25·25	9·84	17·32	2·85
14	·080	2·032	·005027	3·243	17·72	31·22	7·97	14·03	3·52
13	092	2·337	·006648	4·289	23·45	41·25	6·02	10·62	4·65
12	·104	2·642	·008495	5·480	29·95	52·70	4·72	8·30	5·95
11	·116	2·946	·01057	6·819	37·35	65·75	3·779	6·64	7·42
10	·128	3·251	·01287	8·303	45·45	80·1	3·107	5·47	9·03
9	·144	3·658	·01629	10·51	57·4	101·1	2·456	4·32	11·4
8	·160	4·064	·02011	12·97	70·8	124·7	1·990	3·50	14·1
7	·176	4·470	·02433	15·70	85·6	150·7	1·646	2·90	17·0
6	·192	4·877	·02895	18·68	101·9	179·5	1·380	2·430	20·6
5	·212	5·385	·03530	22·77	124·4	219·0	1·132	1·992	24·7
4	·232	5·893	·04227	27·27	148·8	262·0	·925	1·629	30·3
3	·252	6·401	·04988	32·18	175·8	309·5	·802	1·414	34·9
2	·276	7·010	·05983	38·60	211·1	370·7	·670	1·180	41·8
1	·300	7·620	·07069	45·60	249·2	438·2	·567	·998	49·5

TABLE 18.

EFFECTIVE RESISTANCE R' OF COPPER WIRES CARRYING HIGH FREQUENCY CURRENTS
[Zenneck, Table VII., "Wireless Telegraphy."]

NOTE.—The figures give the resistance of 1 m. in ohms., under the assumption that the specific conductivity $\sigma = 5{\cdot}75 \times 10^6$ c.g.s. units.

Diam. of Wire in m.m.	Continuous Current Resistance of 1 Metre in Ohms.	$n=5\times10^4$. λ=6,000 m.	$n=1\times10^5$ λ=3,000 m.	$n=1{\cdot}5\times10^5$. λ=2,000 m.	$n=2\times10^5$. λ=1,500 m.	$n=2{\cdot}5\times10^5$. λ=1,200 m.	$n=3\times10^5$. λ=1000 m.	$n=3{\cdot}5\times10^5$. λ=857 m.
0·2	0·554	0·55	0·56	0·56	0·56	0·56	0·56	0 56
0·4	0·138	0·139	0·141	0·143	0·148	0·152	0·157	0·163
0·6	0·0615	0·063	0·067	0·072	0·078	0·086	0·093	0·099
0·8	0·0346	0·0370	0·0422	0·0498	0·056	0·062	0·067	0·072
1·0	0·0221	0·0254	0·0323	0·0382	0·0434	0·0480	0·052	0·0552
1·2	0·0154	0·0196	0·0262	0·0314	0·0354	0·0393	0·0427	0·0456
1·4	0·0113	0·0164	0·0221	0·0263	0·0298	0·0331	0·0359	0·0384
1·6	0·00865	0·0140	0·0189	0·0226	0·0258	0·0285	0·0311	0·0332
1·8	0·00683	0·0123	0·0169	0.0199	0·0226	0·0251	0·0273	0·0294
2·0	0·00554	0·0110	0·0148	0·0178	0·0202	0·0225	0·0245	0·0263
2·2	0·00457	0·0098	0·0133	0·0159	0·0182	0·0203	0·0221	0·0238
2·4	0·00384	0·0089	0·0121	0·0146	0·0166	0·0185	0·0202	0·0217
2·6	0·00328	0·0081	0·0111	0·0134	0·0153	0·0171	0·0186	0·0200
2·8	0·00282	0·0075	0·0102	0·0123	0·0141	0·0158	0·0172	0·0185
3·0	0·00246	0·0069	0·0095	0·0115	0·0132	0·0147	0·0160	0·0172
3·2	0·00216	0·0065	0·0089	0·0107	0·0123	0·0137	0·0149	0·0161
3·4	0·00192	0·0061	0·0083	0·0101	0·0116	0·0129	0·0141	0·0151
3·6	0·00171	0·0057	0·0079	0·0096	0·0110	0·0122	0·0133	0·0143
3·8	0·00153	0·0053	0·0074	0·0090	0·0103	0·0114	0·0125	0·0134
4·0	0·00138	0·0051	0·0070	0·0085	0·0097	0·0108	0·0118	0·0127
4·2	0·00125	0·00479	0·0066	0·0080	0·0092	0·0103	0·0112	0·0121
4·4	0·00114	0·00456	0·0063	0·0077	0·0088	0·0098	0·0107	0·0115
4·6	0·00105	0·00438	0·0061	0·0074	0·0085	0·0094	0·0103	0·0111
4·8	0·000961	0·00417	0·0058	0·0070	0·0081	0·0090	0·0096	0·0106
5·0	0·000886	0·00400	0.0055	0·0067	0·0077	0·0086	0·0094	0·0101
5·2	0·000819	0·00383	0·0053	0·0065	0·0074	0·0083	0·0090	0·0097
5·4	0·000759	0·00368	0·0051	0·0062	0·0071	0·0080	0·0086	0·0093
5·6	0·000706	0·00354	0·00493	0·0060	0·0069	0·0076	0·0083	0·0091
5·8	0·000658	0·00341	0·00475	0·0058	0·0066	0·0074	0·0081	0·0087
6·0	0·000615	0·00330	0·00458	0·0056	0·0064	0·0071	0·0078	0·0084
6·2	0·000576	0·00319	0·00443	0·0054	0·0062	0·0069	0·0075	0·0081
6·4	0·000541	0·00309	0·00429	0·0052	0·0060	0·0067	0·0073	0·0079
6·6	0·000508	0·00299	0·00415	0·00505	0·0058	0·0064	0·0071	0·0076
6·8	0·000479	0·00290	0·00403	0·00489	0·0056	0·0063	0·0068	0·0074
7·0	0·000452	0·00281	0·00391	0·00475	0·0055	0·0061	0·0067	0·0071
7·2	0·000427	0·00272	0·00379	0·00461	0·0053	0·0059	0·0064	0·0070
7·4	0·000404	0·00265	0·00369	0·00448	0·0051	0·0058	0·0063	0·0067
7·6	0·000383	0·00257	0·00359	0·00433	0·0050	0·0056	0·0061	0·0066
7·8	0·000364	0·00251	0·00350	0·00426	0·00488	0·0055	0·0059	0·0064
8·0	0·000346	0·00244	0·00341	0·00415	0·00477	0·0053	0·0058	0·0063

TABLE 18—*continued.*

Diam. of Wire in m.m.	$n=4\times10^5$. $\lambda=750$ m.	$n=4{\cdot}5\times10^5$. $\lambda=667$ m.	$n=5\times10^5$. $\lambda=600$ m.	$n=10^6$. $\lambda=300$ m.	$n=1{\cdot}5\times10^6$. $\lambda=200$ m.	$n=2\times10^6$. $\lambda=150$ m.	$n=3\times10^6$. $\lambda=100$ m.
0·2	0·56	0·56	0·57	0·61	0·66	0·73	0·86
0·4	0·168	0·175	0·183	0·245	0·293	0·328	0·399
0·6	0·104	0·110	0·115	0·156	0·187	0·213	0·257
0·8	0·076	0·079	0·083	0·110	0·136	0·157	0·190
1·0	0·062	0·065	0·069	0·108	0·124	0·138	0·151
1·2	0·0489	0·051	0·053	0·074	0·089	0·103	0·125
1·4	0·0405	0·0452	0·0450	0·062	0·076	0·087	0·106
1·6	0·0353	0·0372	0·0394	0·054	0·066	0·076	0·093
1·8	0·0314	0·0331	0·0345	0·0480	0·058	0·067	0·083
2·0	0·0278	0·0295	0·0310	0·0432	0·053	0·061	0·074
2·2	0·0254	0·0267	0·0280	0·0392	0·0479	0·0551	0·067
2·4	0·0231	0·0243	0·0243	0·0357	0·0438	0·0506	0·062
2·6	0·0212	0·0224	0·0236	0·0329	0·0400	0·0469	0·057
2·8	0·0196	0·0207	0·0223	0·0307	0·0379	0·0433	0·053
3·0	0·0183	0·0193	0·0204	0·0287	0·0350	0·0405	0·0497
3·2	0·0171	0·0180	0·0190	0·0267	0·0328	0·0381	0·0459
3·4	0·0160	0·0170	0·0178	0·0252	0·0309	0·0357	0·0431
3·6	0·0154	0·0160	0·0168	0·0239	0·0293	0·0337	0·0407
3·8	0·0143	0·0151	0·0159	0·0225	0·0277	0·0314	0·0386
4·0	0·0136	0·0140	0·0151	0·0214	0·0263	0·0300	0·0366
4·2	0·0128	0·0136	0·0145	0·0205	0·0246	0·0285	0·0349
4·4	0·0123	0·0130	0·0138	0·0196	0·0235	0·0272	0·0331
4·6	0·0118	0·0125	0·0131	0·0187	0·0225	0·0260	0·0317
4·8	0·0113	0·0120	0·0127	0·0177	0·0216	0·0250	0·0304
5·0	0·0108	0·0115	0·0124	0·0169	0·0207	0·0240	0·0292
5·2	0·0104	0·0111	0·0116	0·0162	0·0199	0·0229	0·0281
5·4	0·0100	0·0106	0·0112	0·0156	0·0192	0·0220	0·0271
5·6	0·0097	0·0102	0·0108	0·0152	0·0185	0·0213	0·0261
5·8	0·0093	0·0099	0·0104	0·0146	0·0176	0·0203	0·0252
6·0	0·0090	0·0095	0·0101	0·0141	0·0172	0·0199	0·0243
6·2	0·0087	0·0092	0·0098	0·0136	0·0167	0·0192	0·0235
6·4	0·0084	0·0089	0·0095	0·0132	0·0162	0·0186	0·0228
6·6	0·0081	0·0086	0·0092	0·0128	0·0157	0·0181	0·0221
6·8	0·0078	0·0083	0·0088	0·0123	0·0151	0·0175	0·0214
7·0	0·0076	0·0081	0·0085	0·0120	0·0148	0·0172	0·0208
7·2	0·0074	0·0079	0·0083	0·0117	0·0143	0·0166	0·0203
7·4	0·0072	0·0077	0·0081	0·0114	0·0139	0·0160	0·0196
7·6	0·0071	0·0075	0·0079	0·0111	0·0135	0·0156	0·0192
7·8	0·0069	0·0073	0·0077	0·0108	0·0132	0·0152	0·0186
8·0	0·0067	0·0071	0·0075	0·0105	0·0129	0·0148	0·0182

TABLE 19.

TABLE OF VALUES OF LOG. DEC. δ (PER HALF PERIOD) CALCULATED FROM THE ACCURATE FORMULA OF BJERKNES, BY THE AUTHOR.

$$\delta = \frac{\pi}{2}\left(1 - \frac{\lambda_1^2}{\lambda_2^2}\right)\left(\frac{1}{\sqrt{\left(\frac{I_0^2}{I_1^2} - 1\right)}}\right)$$

NOTE.—$\frac{\lambda_1}{\lambda_2}$ must be less than unity, for the equation.

(i.) For wave-lengths taken at the resonance point and below
λ_1 = small wave-length below tune point,
and λ_2 = resonant wave-length.

(ii.) For wave-lengths taken at the resonance point and above
λ_1 = resonant wave-length,
and λ_2 = wave-length slightly greater than λ_1.

The top line in the heading to the tables gives the value of the ratio

$$\frac{\text{Wave length above tune wave}}{\text{Resonant or tune wave-length}} \text{ or } \frac{\lambda_2}{\lambda_1}.$$

The second line gives $\frac{\lambda_1}{\lambda_2}$.

Similarly $\frac{I_0}{I_1}$ and $\frac{I_1}{I_0}$ are tabulated, as the latter is sometimes useful when tuning curves have been plotted with I_1 = unity as ordinates.

$\frac{I_1}{I_0}$.	$\frac{I_0}{I_1}$.	1·01 $\frac{\lambda_1}{\lambda_2}$ = ·99.	1·02 $\frac{\lambda_1}{\lambda_2}$ = ·98.	1·03 $\frac{\lambda_1}{\lambda_2}$ = ·97.	1·04 $\frac{\lambda_1}{\lambda_2}$ = ·96.	1·05 $\frac{\lambda_1}{\lambda_2}$ = ·95.	1·06 $\frac{\lambda_1}{\lambda_2}$ = ·94.	1·07 $\frac{\lambda_1}{\lambda_2}$ = ·93.
·995	1·005	·3126	·6220	·9284	1·2314			
·994	1·006	·2869	·5709	·8521	1·1302			
·993	1·007	·2664	·5304	·7912	1·0495			
·992	1·008	·2482	·4939	·7371	·9777			
·991	1·009	·2332	·4640	·6925	·9185			
·990	1·010	·2205	·4388	·6549	·8688	1·0804		
·989	1·011	·2104	·4187	·6249	·8289	1·0308		
·988	1·012	·2012	·4005	·5976	·7928	·9859		
·987	1·013	·1932	·3845	·5739	·7615	·9467		
·986	1·014	·1865	·3709	·5536	·7347	·9132		
·985	1·015	·1800	·3584	·5349	·7095	·8825		
·984	1·016	·1741	·3465	·5172	·6859	·8531	1·0180	
·983	1·017	·1687	·3358	·5010	·6645	·8266	·9866	
·982	1·018	·1638	·3261	·4866	·6450	·8032	·9591	
·981	1·019	·1594	·3172	·4730	·6278	·7808	·9319	
·980	1·020	·1555	·3094	·4618	·6125	·7617	·9092	1·0560
·979	1·021	·1526	·3025	·4512	·5988	·7447	·8889	1·0326
·978	1·022	·1486	·2958	·4412	·5857	·7282	·8691	1·0095
·977	1·023	·1454	·2893	·4317	·5725	·7122	·8501	·9876
·977	1·024	·1422	·2831	·4225	·5602	·6969	·8319	·9663
·976	1·025	·1393	·2771	·4136	·5486	·6823	·8144	·9461
·975	1·026	·1366	·2716	·4054	·5377	·6687	·7981	·9271
·974	1·027	·1340	·2664	·3976	·5274	·6559	·7828	·9094
·973	1·028	·1316	·2616	·3905	·5179	·6442	·7688	·8931
·972	1·029	·1293	·2572	·3839	·5092	·6332	·7557	·8780
·971	1·030	·1271	·2529	·3775	·5007	·6227	·7432	·8634
·969	1·0325	·1221	·2430	·3628	·4813	·5983	·7140	·8296
·966	1·0350	·1177	·2343	·3497	·4639	·5769	·6885	·7998
·964	1·0375	·1138	·2264	·3378	·4481	·5573	·6652	·7727
·962	1·040	·1100	·2189	·3266	·4333	·5388	·6431	·7471
·957	1·045	·1032	·2054	·3065	·4066	·5056	·6035	·7010
·952	1·050	·0976	·1941	·2897	·3843	·4779	·5705	·6626
·948	1·055	·0926	·1839	·2745	·3641	·4529	·5404	·6278
·943	1·060	·0883	·1756	·2621	·3477	·4324	·5161	·5994

TABLE 19—*continued.*

$\frac{I_1}{I_0}$.	$\frac{I_0}{I_1}$.	1·01 $\frac{\lambda_1}{\lambda_2}$ = ·99.	1·02 $\frac{\lambda_1}{\lambda_2}$ = ·98.	1·03 $\frac{\lambda_1}{\lambda_2}$ = ·97.	1·04 $\frac{\lambda_1}{\lambda_2}$ = ·96.	1·05 $\frac{\lambda_1}{\lambda_2}$ = ·95.	1·06 $\frac{\lambda_1}{\lambda_2}$ = ·94.	1·07 $\frac{\lambda}{\lambda_2}$ = ·93.
·939	1·065	·0845	·1681	·2500	·3329	·4138	·4939	·5737
·935	1·070	·0811	·1613	·2409	·3196	·3972	·4741	·5506
·930	1·075	·0781	·1554	·2319	·3076	·3826	·4566	·5304
·926	1·080	·0753	·1499	·2238	·2966	·3689	·4404	·5120
·922	1·085	·0729	·1452	·2165	·2871	·3572	·4263	·4951
·917	1·090	·0709	·1410	·2106	·2793	·3474	·4144	·4816
·913	1·095	·0693	·1380	·2059	·2736	·3397	·4055	·4710
·909	1·10	·0682	·1358	·2026	·2688	·3343	·3990	·4634
·869	1·15	·0551	·1091	·1636	·2170	·2698	·3221	·3740
·833	1·20	·0472	·0939	·1401	·1858	·2311	·2758	·3203
·800	1·25	·0416	·0828	·1236	·1639	·2039	·2434	·2827
·769	1·30	·0376	·0749	·1118	·1483	·1844	·2201	·2556
·741	1·35	·0345	·0686	·1023	·1359	·1688	·2015	·2340
·714	1·40	·0319	·0636	·0949	·1259	·1565	·1868	·2170
·690	1·45	·0298	·0593	·0885	·1176	·1459	·1741	·1897
·667	1·50	·0279	·0556	·0828	·1103	·1368	·1633	·1897
·645	1·55	·0264	·0526	·0785	·1041	·1294	·1545	·1794
·625	1·60	·0250	·0498	·0743	·0986	·1226	·1465	·1700
·606	1·65	·0238	·0474	·0707	·0938	·1166	·1392	·1617
·588	1·70	·0227	·0452	·0675	·0895	·1113	·1328	·1544
·571	1·75	·0217	·0433	·0646	·0857	·1066	·1272	·1477
·556	1·80	·0209	·0415	·0619	·0822	·1022	·1220	·1417
·540	1·85	·0200	·0399	·0595	·0789	·0982	·1172	·1361
·526	1·90	·0193	·0384	·0573	·0760	·0945	·1129	·1311
·513	1·95	·0186	·0371	·0553	·0734	·0912	·1089	·1265
·500	2·00	·01804	·03590	·05358	·07108	·08840	·10550	·12254
·488	2·05	·01747	·03480	·05191	·06888	·08566	·10224	·11879
·476	2·10	·01692	·03371	·05028	·06672	·08295	·09904	·11507
·465	2·15	·01640	·03264	·04870	·06461	·08032	·09589	·11138
·454	2·20	·01588	·03159	·04720	·06256	·07777	·09281	·10780
·444	2·25	·01544	·03061	·04580	·06059	·07538	·08993	·10456
·435	2·30	·01502	·02980	·04460	·05898	·07335	·08755	·10170
·426	2·35	·01466	·02907	·04350	·05756	·07162	·08542	·09924
·417	2·40	·01432	·02841	·04252	·05625	·06995	·08350	·09697
·408	2·45	·01398	·02778	·04158	·05499	·06834	·08162	·09481
·400	2·50	·01364	·02716	·04053	·05376	·06676	·07976	·09269
·392	2·55	·01331	·02655	·03955	·05253	·06521	·07792	·09060
·385	2·60	·01300	·02594	·03865	·05130	·06371	·07610	·08855
·377	2·65	·01270	·02534	·03775	·05008	·06227	·07432	·08652
·370	2·70	·01242	·02476	·03692	·04898	·06092	·07270	·08452
·364	2·75	·01216	·02422	·03613	·04794	·05962	·07115	·08265
·357	2·80	·01192	·02371	·03537	·04692	·05837	·06965	·08091
·351	2·85	·01167	·02323	·03467	·04598	·05720	·06826	·07929
·345	2·90	·01145	·02279	·03401	·04509	·05610	·06695	·07778
·339	2·95	·01124	·02237	·03338	·04426	·05507	·06568	·07636
·333	3·00	·01105	·02199	·03282	·04353	·05413	·06462	·07504
·308	3·25	·01012	·02013	·03005	·03986	·04957	·05900	·06895
·286	3·50	·00928	·01847	·02756	·03656	·04547	·05437	·06320
·267	3·75	·00864	·01718	·02564	·03401	·04237	·05057	·05863
·250	4·00	·00806	·01607	·02398	·03180	·03955	·04721	·05483
·235	4·25	·00753	·01499	·02237	·02967	·03690	·04404	·05115
·222	4·50	·00707	·01404	·02095	·02779	·03465	·04128	·04801
·211	4·75	·00669	·01332	·01988	·02637	·03280	·03914	·04547
·200	5·00	·00638	·01270	·01896	·02514	·03127	·03732	·04337
·167	6	·00528	·01052	·01569	·02082	·02589	·03090	·03589
·143	7	·00451	·00897	·01338	·01775	·02207	·02635	·03059
·125	8	·00394	·00784	·01170	·01552	·01930	·02303	·02675
·111	9	·00350	·00696	·01038	·01377	·01713	·02044	·02374
·100	10	·00314	·00625	·00933	·01238	·01540	·01838	·02135
·091	11	·00284	·00565	·00842	·01175	·01390	·01659	·01926
·083	12	·00262	·00521	·00777	·01031	·01282	·01530	·01777

TABLE 20.

Table for the Determination of the Degree of Coupling K'.

N', N'', are the two frequencies corresponding to the two coupling peaks of the tuning curve.

λ' λ'', are the two corresponding wave-lengths.

N and λ are the frequency and wave-length for the circuits when uncoupled.

$$K' = \frac{\left(1 - \frac{N''}{N'}\right)^2}{\left(1 + \frac{N''}{N}\right)^2} = \frac{1 - \left(\frac{\lambda'}{\lambda''}\right)^2}{1 + \left(\frac{\lambda'}{\lambda''}\right)^2}.$$

In the following table the coupling is expressed as a percentage.

[Zenneck, "Wireless Telegraphy," Table X.]

$\frac{\lambda'}{\lambda}$ or $\frac{N}{N'}$.	Percentage Coupling.	$\frac{\lambda''}{\lambda}$ or $\frac{N}{N''}$.	Percentage Coupling.	$\frac{\lambda''}{\lambda'}$ or $\frac{N'}{N''}$.	Percentage Coupling.
0·999	0·20	1·001	0·20	1·001	0·100
0·998	0·40	1·002	0·40	1·002	0·200
0·997	0·60	1·003	0·60	1·003	0·299
0·996	0·80	1·004	0·80	1·004	0·398
0·995	1·00	1·005	1·00	1·005	0·498
0·994	1·20	1·006	1·20	1·006	0·596
0·993	1·40	1·007	1·40	1·007	0·695
0·992	1·59	1·008	1·61	1·008	0·799
0·991	1·79	1·009	1·81	1·009	0·897
0·99	1·99	1·01	2·01	1·01	0·99
0·98	3·96	1·02	4·04	1·02	1·98
0·97	4·91	1·03	6·09	1·03	2·97
0·96	7·84	1·04	8·16	1·04	3·92
0·95	9·75	1·05	10·2	1·05	4·87
0·94	11·6	1·06	12·4	1·06	5·82
0·93	13·5	1·07	14·5	1·07	6·76
0·92	15·4	1·08	16·6	1·08	7·68
0·91	17·2	1·09	18·8	1·09	8·60
0·90	19·0	1·10	21·0	1·10	9·50
0·89	20·8	1·11	23·2	1·11	10·4
0·88	22·6	1·12	25·4	1·12	11·3
0·87	24·3	1·13	27·7	1·13	12·2
0·86	26·0	1·14	30·0	1·14	13·0
0·85	27·8	1·15	32·2	1·15	13·9
0·84	29·4	1·16	34·6	1·16	14·7
0·83	31·1	1·17	36·9	1·17	15·6
0·82	32·8	1·18	39·2	1·18	16·4
0·81	34·4	1·19	41·6	1·19	17·2
0·80	36·0	1·20	44·0	1·20	18·0

TABLE 20—*continued.*

$\frac{\lambda'}{\lambda}$ or $\frac{N}{N'}$.	Percentage Coupling.	$\frac{\lambda''}{\lambda}$ or $\frac{N}{N''}$.	Percentage Coupling.	$\frac{\lambda''}{\lambda'}$ or $\frac{N'}{N''}$.	Percentage Coupling.
0·79	37·6	1·21	46·4	1·21	18·8
0·78	39·2	1·22	48·8	1·22	19·6
0·77	40·7	1·23	51·3	1·23	20·4
0·76	42·2	1·24	53·8	1·24	21·2
0·75	43·8	1·25	56·2	1·25	22·0
0·74	45·2	1·26	58·8	1·26	22·7
0·73	46·7	1·27	61·3	1·27	23·5
0·72	48·2	1·28	63·8	1·28	24·2
0·71	49·6	1·29	66·4	1·29	24·9
0·70	51·0	1·30	69·0	1·30	25·6
0·69	52·4			1·31	26·4
0·68	53·8			1·32	27·1
0·67	55·1			1·33	27·8
0·66	56·4			1·34	28·5
0·65	57·8			1·35	29·1
0·64	59·0			1·36	29·8
0·63	60·3			1·37	30·5
0·62	61·6			1·38	31·1
0·61	62·8			1·39	31·8
0·60	64·0			1·40	32·4
				1·41	33·0
				1·42	33·7
				1·43	34·3
				1·44	34·9
				1·45	35·5
				1·46	36·1
				1·47	36·7
				1·48	37·3
				1·49	37·9
				1·50	38·5
				1·55	41·2
				1·60	43·8
				1·65	46·3
				1·70	48·6
				1·75	50·7
				1·80	52·8
				1·85	54·8
				1·90	56·6
				1·95	58·4
				2·00	60·0

TABLE 21.

SPECIFIC INDUCTIVE CAPACITIES.

(By permission of the proprietors of "The Electrician.")

The *specific inductive capacity* of a substance is the ratio of the capacity of a condenser when the plates are separated by this substance to the capacity of the same condenser when its plates are separated by air at about 760 mm. pressure—no change being made in the condenser except in the substitution of air for the substance in question.

The determination of the specific inductive capacity of a substance does not admit of great accuracy on account of the phenomenon of absorption or soaking in of the charge which causes an apparent diminution * in the specific inductive capacity for charges of short duration as compared with those of long duration. The figures given in the following table should, therefore, only be regarded as approximately correct.

Substance.	Specific Inductive Capacity.	Authority.
Flint glass, very light, density 2·87	6·61	J. Hopkinson
,, light, density 3·2	6·72	J. Hopkinson
,, ,, ,,	3·01	Wüllner
,, dense, density 3·66	7·38	J. Hopkinson
,, ,, ,,	3·05	Wüllner
,, extra dense, density 4·5	9·90	J. Hopkinson
,, ,, ,,	3·16	Wüllner
Crown glass, hard, density 2·485	6·96	J. Hopkinson
,,	3·11	Wüllner
Plate glass	8·45	J. Hopkinson
,,	5·83 to 6·34	Wüllner
White mirror glass	5·83	Schiller
,, ,,	6·34	Siemens
Straw-coloured glass	2·96 to 3·66	Schiller
,, ,,	4·12	Siemens
Paraffin wax	1·977	Gibson & Barclay
,, ,,	1 96	Wüllner
,, ,,	2·32	Boltzman
,, ,,	1·68 to 1·92	Schiller
,, ,,	2·19 to 2·34	Siemens
Indiarubber, pure	2·12	Schiller
,, ,,	2·34	Siemens
,, vulcanised	2·69	Schiller
,, ,,	2·94	Siemens
Resin	2·55	Boltzman
Ebonite	2·21 to 2·76	Schiller
,,	3·15	Boltzman
,,	2·56	Wüllner
,,	2·28	Gordon
Sulphur	2·88 to 3·21	Wüllner
,,	3 84	Boltzman
,,	2·58	Gordon
Shellac	2·74	Gordon
,,	2·95 to 3·73	Wüllner
,,	3·15	Boltzman
Gutta-percha	4·2	Faraday
,,	2·46	Gordon
Mica	5·0	Faraday
Pitch	1·8	Faraday
Petroleum, spirit, Field's	1·92	J. Hopkinson
,, essence of	2·17	Perot
,, oil, Field's	2·07	J. Hopkinson
,, ,, common	2·10	J. Hopkinson
,, ,,	2·04 to 2·07	Silow
,, ,, neutral at 21° C.	2·26	E. B. Rosa
Turpentine, commercial	2·23	J. Hopkinson
,, ,, at 18·6° C.	2·43	E. B. Rosa
,, oil of, at 17·1° C.	1·94	Quincke
,, ,,	2·16 to 2·22	Silow
Castor oil	4·78	J. Hopkinson
Sperm oil	3·02	J. Hopkinson
,, at 20° C.	3·09	E. B. Rosa
Benzine	2·20	Silow
,,	2·24	Perot
,, at 21° C.	2·45	E. B. Rosa
Bisulphide of carbon at about 11° C.	1·97 to 2·22	Quincke
,, ,, ,, ,,	1·81	Gordon
Water at 14° C.	83·8	Tereschin
,, 25° C.	75·7	E. B. Rosa
Air at about 0·001 mm. pressure	0·94	Ayrton
,, ,, 5 ,, ,,	0·9985	Ayrton
,, ,, 760 ,, ,,	0·9994	Boltzman
Hydrogen at about 760 mm. pressure	0·9997	Boltzman
,, ,, ,, ,, ,,	0·9998	Ayrton
Carbon dioxide at about 760 mm. pressure	1·0004	Boltzman
,, ,, ,, ,, ,,	1·0008	Ayrton
Olefiant gas at about 760 mm. pressure	1·0007	Boltzman
Sulphur dioxide at about 760 mm. pressure	1·0037	Ayrton

* According to M. Perot the reverse is sometimes the case with impure liquids.

TABLE 22.

SPECIFIC ELECTRICAL RESISTANCE TABLE.

METALS, ALLOYS, ELECTROLYTES.

(*By permission of the Proprietors of the "Electrician."*)

METALS AND ALLOYS.

Metal or Alloy.	Resistance Compared with Copper (approx.)	Specific* Resistance in C.G.S. Units at 0° C.	Temperature Coefficient per 1° C.
Aluminium, annealed	2	2,946	0·0039
,, hard-drawn	2	3,160	0·0039
Antimony, pressed	22½	35,900	0·0039
Bismuth, pressed	83	132,650	0·0054
Cadmium	6¼	6,800	—
Carbon, retort	42,000	67×10^6	—
,, arc light (Carré)	4,400	7×10^6	—0·0005
,, glow lamp (Edison-Swan)	2,500	4×10^6	—0·00054
Copper, soft	1	1,580	0·00388
,, hard	1	1,616	0·00388
German silver (Cu 4 parts, Ni 2 parts, Zn 1 part).	13¼	21,170	0·00044
Gold, purest soft	1⅓	1,952	0·00336
,, hard-drawn	1⅓	2,118	0·00365
Iron	6	9,611	0·0048
Lead, pressed	12¼	19,850	0·00387
Lead peroxide, chemically prepared.	4×10^6	$5{,}590 \times 10^6$	—†
,, ,, electrolytically prepared.	4×10^6	$6{,}780 \times 10^6$	—†
Mercury, liquid	59	94,070	0·00072
Manganin (Cu 84 per cent., Mn 12 per cent., Ni 4 per cent.).	26	42,000	0° to 10° C. = + 0·000025 10° to 20° C. = + 0·000014 20° to 30° C. = + 0·000003 30° to 40° C. = 0 40° to 50° C. = — 0·000003 50° to 60° C. = — 0·000006
Manganese copper (Cu 70 per cent., Mn 30 per cent.).	63	100,600	0·00004
Nickel, pure	7½	12,290	0·0048
Platinum, pure annealed	5	8,222	0·0032
Platinoid (German silver + 1 or 2 per cent. of Tungsten).	27½	43,600	0·00025
Platinum iridium (Pt = 80 per cent., Ir = 20 per cent.).	18⅓	29,375	0·00089
Platinum silver (Pt = 33 per cent., Ag = 66 per cent.).	16⅔	26,820	0·00018
Phosphor bronze, commercial	5⅓	8,479	0·00064
Silver, annealed	—	1,521	0·00377
,, hard-drawn	—	1,652	—
Tin, pure	6	9,565	0·004
,, pressed	8⅓	13,360	0·0036
Zinc, pressed	3½	5,690	0·0036

* To convert to ohms $\times 10^{-9}$.

† John Shields, *Chem. News*, "No alteration observed on heating up to 115° C."

TABLE 22A

Volume Resistivity of Solid Dielectrics.

[Values of the resistivity taken from the "Bull. Bureau of Standards," Vol. XI., Table 8].

Material.	Resistivity in Ohms per cm.³ at 22° C.	Material.	Resistivity in Ohms per cm.³ at 22° C.
Amberite	5×10^{16}	Marble, Blue Vermont	1×10^{9}
Bakerlite No. L558	2×10^{16}	Mica, Black Spotted African	4×10^{13}
,, No. 140	Max. 2×10^{7} Min.	,, Brown African clear	2×10^{15}
Beeswax, Yellow	2×10^{15}	,, Colourless	2×10^{17}
,, White	6×10^{14}	,, India ruby, stained	5×10^{13}
Celluloid, White	2×10^{10}	,, ,, ,, slightly stained.	5×10^{16}
Ceresin	over 5×10^{18}	Moulded Mica	1×10^{15}
Duranoid	3×10^{15}	Paraffin (Special)	over 5×10^{18}
Electrose, No. 8	2×10^{16}	,, (Parowax)	1×10^{16}
,, Black	1×10^{14}	Porcelain, Unglazed	3×10^{14}
,, Yellow	5×10^{15}	Quartz, ∥ to axis	2×10^{14}
Fibre, Hard	2×10^{10}	,, ⊥ to axis	2×10^{16}
Red	5×10^{9}	,, Fused	over 5×10^{18}
Glass,* Bohemian	$*6 \times 10^{12}$	Rosin	5×10^{16}
,, German	5×10^{11}	Sealing Wax	8×10^{15}
,, Kavalier	8×10^{15}	Shellac	1×10^{16}
,, Opal	1×10^{12}	Slate	1×10^{8}
,, * Ordinary	$*9 \times 10^{13}$	Stabalite	3×10^{13}
,, Plate	2×10^{13}	Sulphur	1×10^{17}
Glyptol	1×10^{16}	Tetrachlornaphthalene	5×10^{13}
Hard Rubber	1×10^{18}	Vulcabeston	$†2 \times 10^{10}$
,,	$*2 \times 10^{15}$	Wood, Paraffined*	5×10^{10}
Ivory	2×10^{8}	,, Mahogany	4×10^{13}
Khotinsky Cement	2×10^{15}	,, Maple	3×10^{10}
Marble, Italian	1×10^{11}	,, Poplar	5×10^{11}
,, Pink Tennessee	5×10^{9}		

* Tables of the French Physical Society.
† Should read "J—P Bakerlite."

TABLE 23.

Relation between Sparking Distances and Impressed Voltage.

In the Standardisation Rules of the American Institute of Electrical Engineers, the following table of sparking distances in air between opposed sharp needle points for various effective sinusoidal voltage is given :—

Kilovolts sq. root of mean sq.	Inches sparking distance.	Kilovolts sq. root of mean sq.	Inches sparking distance.	Kilovolts sq. root of mean sq.	Inches sparking distance.
5	0·225	80	7·1	200	20·25
10	0·47	90	8·35	210	21·30
15	0·725	100	9·6	220	22·35
20	1·0	110	10·75	230	23·40
25	1·3	120	11·85	240	24·45
30	1·625	130	12·90	250	25·50
35	2·0	140	13·95	260	26·50
40	2·45	150	15·0	270	27·50
45	2·95	160	16·5	280	28·50
50	3·55	170	17·10	290	29·50
60	4·65	180	18·15	300	30·50
70	5·85	190	19·20		

Recent tests show that needle-point gaps are not reliable above 100,000 volts. A sphere gap voltmeter is recommended by S. W. Farnsworth and C. L. Fortescue (*Proc. Am. Inst. E.E.*, Feb., 1913), and the tests made by the latter and L. W. Chubb give the following results :—

Diam. of Spheres in cm.	Gap in cm.	Volts.
25	2	60,000
25	4	112,000
25	6	165,000
50	8	215,000
50	10	260,000
50	14	350,000

TABLE 24.

TABLE OF DISRUPTIVE VOLTAGES TAKEN BETWEEN CLEAN BRASS BALLS OF THE DIFFERENT SIZES.

v = p. d. in volts. (max.).
d = diameter of spark balls in cms.
l = spark length in centimetres.

(J. A. Fleming, "Principles of Electric Wave Telegraphy, p. 153.)

d = 5·0.		d = 2·0.		d = 1·0.	d = 0·5.
l	v	l	v	v	v
5	18,360	1	4,710	4,800	4,830
6	21,600	2	8,100	8,370	8,370
7	24,540	3	11,370	11,370	11,340
8	27,330	4	14,490	14,550	13,770
9	30,090	5	17,490	17,310	15,720
10	32,850	6	20,370	19,920	17,190
11	35,580	7	23,250	22,050	18,300
12	38,310	8	26,040	24,090	19,020
13	41,010	10	31,290	27,000	20,190
14	43,680	12	35,490	—	—
15	46,230	14	38,640	—	—
16	48,660	15	—	—	22,320
—	—	16	41,280	—	—

TABLE 25.

TABLE OF SPARK RESISTANCES IN OHMS BETWEEN 1 CM. BALLS.

(J. A. Fleming, "Principles of Electric Wave Telegraphy," p. 184.)

Spark Length in cms.	Material of Balls.				
	Brass.	Copper.	Aluminium.	Zinc.	Iron.
0·05	0·9	1·3	1·3	1·0	0·9
0·10	2·4	2·8	2·8	2·2	2·2
0·15	4·0	4·4	4·6	3·5	4·5
0·20	5·9	6·4	7·1	5·6	7·7
0·25	8·9	9·3	10·6	8·4	11·8
0·30	12·8	12·6	15·5	12·2	16·4

TABLE 26.

Table of Dielectric Strengths.

(Values given in "Fowler's Electrical Engineer's Pocket Book.")

Material.	Practical Value in Volts per mil.	Thickness for which Values hold, in inches.
Cotton, Single Covering	275	0·005 —0·012
,, ,, Soaked in Paraffin Wax	400	0·006 —0·015
,, Double Covering	225	0·012 —0·020
,, ,, Soaked in Paraffin Wax	275	0·015 —0·025
Fibre, Red Vulcanised	200	0·030 —0·075
Mica	3000	0·001 —0·125
Micanite Cloth, Flexible.	200	0·008 —0·020
Oiled Paper	500	0·005 —0·030
,, ,, Double Coat	700	0·006 —0·010
Paraffined Paper	900	0·002 —0·008
Shellacked Cloth	40	0·006 —0·012
Single Silk Covering, S.S.C.	475	0·001 —0·0025
,, ,, ,, Shellacked	525	0·0015—0·004
Double Silk Covering, D.S.C.	375	0·0015—0·005
,, ,, ,, Shellacked . . .	450	0·002 —0·007

TABLE 26A.

Table of Dielectric Strengths.

(Values given in "Standard Handbook for Electrical Engineers.")

Material.	Volts per mm.
Celluloid	14,000
Ebonite	30,000
Empire Cloth	10,000
Fuller Board	16,000
Glass, Ordinary	8,000
,, Lead	5,500
Manilla Paper.	5,000
Micanite Plate	40,000
,, Flexible Plate	30,000
,, Cloth	17,000
,, Paper	18,000
Paraffin	11,500
Porcelain	9,000
,, (Locke)	16,350
Pressphan	4,000 / 10,000
Resin	11,000
Wax	11,500

TABLE 27.

GILBERT'S TABLE (ORDINARY CATENARY).

$x = 100 =$ half span.

c = Modolus.	d = dip.	s = length of wire.	l = ordinate at insulator.	90° − i°.		
				°	′	″
2000	2·500511	100·041474	2002·500511	87	8	11
1950	2·564593	100·042440	1952·564593	87	3	46
1900	2·632163	100·045727	1902·632163	86	59	8
1850	2·703298	100·047540	1852·703298	86	54	15
1800	2·778421	100·050163	1802·778421	86	49	6
1750	2·857914	100·054318	1752·857914	86	43	40
1700	2·942018	100·057566	1702·942018	86	37	53
1650	3·031204	100·060788	1653·031204	86	31	46
1600	3·125974	100·064421	1603·125974	86	25	16
1550	3·226852	100·068245	1553·226852	86	18	21
1500	3·334558	100·073939	1503·334558	86	10	59
1450	3·449618	100·078929	1453·449618	86	3	6
1400	3·572907	100·084490	1403·572907	85	54	39
1350	3·705344	100·090750	1353·705344	85	45	35
1300	3·847958	100·097440	1303·847958	85	35	45
1250	4·002035	100·105463	1254·002035	85	25	16
1200	4·168981	100·114680	1204·168981	85	13	51
1150	4·350543	100·125801	1154·350543	85	1	26
1100	4·548545	100·137346	1104·548545	84	47	54
1050	4·765440	100·150553	1054·765440	84	33	5
1000	5·004084	100·165906	1005·004084	84	16	48
980	5·106408	100·173025	985·106408	84	9	49
960	5·213007	100·180582	965·213007	84	2	13
940	5·324098	100·188974	945·324098	83	54	58
920	5·440045	100·196191	925·440045	83	47	4
900	5·561266	100·205825	905·561266	83	38	48
880	5·687876	100·214837	885·687876	83	30	11
860	5·820479	100·225255	865·820479	83	21	9
840	5·959364	100·235949	845·959364	83	11	42
820	6·105033	100·247321	826·105038	83	1	47
800	6·258102	100·260296	806·258102	82	51	23
780	6·418938	100·273356	786·418938	82	40	28
760	6·588360	100·288153	766·588360	82	28	57
740	6·767004	100·304328	746·767004	82	16	50
720	6·955577	100·321527	726·955577	82	4	3
700	7·154926	100·339869	707·154926	81	50	33
680	7·366193	100·360765	687·366193	81	36	15
660	7·590181	100·382517	667·590181	81	21	6
640	7·828368	100·407143	647·828368	81	5	1
620	8·081923	100·433570	628·081923	80	47	54
600	8·352608	100·463404	608·352608	80	29	40
580	8·642033	100·495985	588·642033	80	10	11
560	8·952299	100·532176	568·952299	79	49	27
540	9·283888	100·562366	549·283888	79	27	2
520	9·645021	100·617335	529·645021	79	2	56
500	10·033315	100·667683	510·033315	78	36	59
480	10·454508	100·725490	490·454508	78	8	55
460	10·912412	100·789382	470·912412	77	38	28
440	11·412622	100·863052	451·412622	77	5	23
420	11·961025	100·947150	431·961025	76	29	6

TABLE 27.—*continued.*

c = Modolus.	d = dip.	s = length of wire.	l = ordinate at insulator.	$90° - i°$.		
				°	′	″
400	12·565207	101·044792	412·565207	75	49	22
380	13·233994	101·158163	393·233994	75	5	35
360	13·978365	101·290757	373·978365	74	17	7
340	14·812141	101·447796	354·812141	73	32	10
320	15·752501	101·635337	335·752501	72	22	46
300	16·821529	101·862069	316·821529	71	14	44
280	18·047685	102·139232	298·047685	69	57	31
260	19·468993	102·483745	279·468993	68	29	13
240	21·126437	102·893226	261·126437	66	47	38
220	23·118850	103·473548	243·118850	64	48	38
200	25·525175	104·219022	225·525175	62	28	34
180	28·559946	105·343499	208·559946	59	39	43
160	32·280531	106·638654	192·280531	56	19	0
140	37·258541	108·722538	177·258541	52	10	2
120	44·134402	111·982596	164·134402	46	58	48
100	54·308027	117·520071	154·308027	40	23	42
95	57·674415	119·517684	152·674415	38	28	45
90	61·511583	121·884206	151·511583	36	26	34
85	65·852160	124·624934	150·852160	34	17	44
80	74·073875	128·153485	151·073875	31	58	28
75	77·147407	132·377616	152·147407	29	32	4
70	84·433443	137·657866	154·433443	26	57	10

NOTES ON THE USE OF THE TABLE.

Let the distance between the points of support be 2,000 ft. Then x, the half-span, is 1,000 ft. In the table x is represented by 100; therefore every unit in the Table represents 10 ft.

Let the required sag be 30 ft., or 3 units of dip. The nearest to this in column 2 is $d = 3·031$.

In column 5 we find that the angle which the catenary will make with the vertical through the point of support is $86° \; 31' \; 46''$.

In column 3 we find that the actual length of the catenary will be 100·060788 units, or 1,000·61 ft.

In column 1 we find that the modulus c is 1,650. This modulus multiplied by the weight per unit length gives the tension at the lowest (mid-) point.

Thus if the wire forming the catenary weighs 100 lbs. per 1,000 yards, or $\frac{1}{30}$ lb. per foot, the weight per unit of the table is $\frac{1}{3}$ lb., and the tension at the lowest point will be $1,650 \times \frac{1}{3}$, or 550 lbs., due to weight of wire alone.

The tension at the point of suspension is found by adding to this mid-point tension the product of the sag in feet into the weight of wire per foot; that is, in this case, by adding 1 lb.

TABLE 28.

Weights and Measures.

Avoirdupois Weight.

drachms.	ozs.	lbs.	qrs.	cwts.	ton.	grammes.
1 =	·0625 =	·0039 =	·000139 =	·000035 =	·00000174 =	1·771846
16 =	1 =	·0625 =	·00223 =	·000558 =	·000028 =	28·34954
256 =	16 =	1 =	·0357 =	·00893 =	·000447 =	453·59
7,168 =	448 =	28 =	1 =	·25 =	·0125 =	12,700
28,672 =	1,792 =	112 =	4 =	1 =	·05 =	50,802
573,440 =	35,840 =	2.240 =	80 =	20 =	1 =	1,016,048

Troy Weight.

rains.	dwts.	ozs.	lbs.	grammes.
1 =	·04167 =	·00208 =	·0001736 =	·0648
24 =	1 =	·05 =	·004167 =	1·555
480 =	20 =	1 =	·0833 =	31·1035
5,760 =	240 =	12 =	1 =	373·242

7,000 grains troy = 1 lb. avoirdupois.
175 lbs. troy = 144 lbs. avoirdupois.
lbs. avoirdupois × 1·2153 = lbs. troy.
lbs. troy × ·82286 = lbs. avoirdupois.

Long Measure.

ins.	feet.	yards.	fath.	poles	fur.	mile.	metres.
1 =	·083 =	·02778 =	·0139 =	·005 =	·000126 =	·0000158 =	·0254
12 =	1 =	·333 =	·1667 =	·0606 =	·00151 =	·0001894 =	·3048
36 =	3 =	1 =	·5 =	·182 =	·00454 =	·000568 =	·9144
72 =	6 =	2 =	1 =	·364 =	·0091 =	·001136 =	1·8287
198 =	16½ ×	5½ =	2¾ =	1 =	·025 =	·003125 =	5·0291
7,920 =	660 =	220 =	110 =	40 =	1 =	·125 =	201·16
63,360 =	5,280 =	1,760 =	880 =	320 =	8 =	1 =	1,609·315

Measure of Capacity.

pints.	gall.	peck.	bushel.	quarter.	wey.	last.	cub. ft.	litres.
1 =	·125 =	·0625 =	·01562 =	·00195 =	·00039 =	·000195 =	·02 =	·5676
8 =	1 =	·5 =	·125 =	·0156 =	·00312 =	·00156 =	·1604 =	4·543
16 =	2 =	1 =	25 =	·03125 =	·00625 =	·00312 =	·3208 =	9·082
64 =	8 =	4 =	1 =	·125 =	·025 =	·0125 =	1·283 =	36·32816
512 =	64 =	32 =	8 =	1 =	·2 =	·1 =	10·264 =	290·625
2,560 =	320 =	160 =	40 =	5 =	1 =	·5 =	51·319 =	1,453·126
5,120 =	640 =	320 =	80 =	10 =	2 =	1 =	102·64 =	2,906·25

1 gallon in wine, ale, or dry measure
= 277¼ cubic inches = ·16 cubic foot
= 10 lbs. of distilled water.
Cubic feet × 6·2355 = gallons.
Cubic ins. × ·003607 = gallons.
1 bushel = 2,218·19 cubic inches = 1·28 cubic foot.
Cubic feet = ·78 = bushels.
Cubic ins. × ·00045 = bushels.

Square or Surface Measure.

144 square inches = 1 square foot.
9 square feet = 1 square yard.
30¼ square yards = 1 square rod or perch.
40 square rods = 1 rood.
4 roods = 1 acre (4,840 square yards).
640 acres = 1 square mile (3,097,600 square yards).

TABLE 29.

SYNOPSIS OF UNITS.

		Dimensions.
I.—FUNDAMENTAL.		
Length—Mass—Time		$L - M - T$
II.—DERIVED MECHANICAL.		
Area	$= L \times L$	L^2
Volume	$= L \times L \times L$	L^3
Velocity	$V = L \div T$	LT^{-1}
Momentum	= mass ÷ velocity	LMT^{-1}
Acceleration	A = velocity ÷ time	LT^{-2}
Force	F = mass × acceleration	LMT^{-2}
Work	W = force × length	L^2MT^{-2}
Energy (kinetic)	= ½ mass × velocity²	L^2MT^{-2}
III.—DERIVED ELECTRO-STATIC.		
Quantity	$q = vQ = \sqrt{\text{force} \times \text{distance}^2}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}$
Current	$c = vI$ = quantity ÷ time	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}$
Electro-motive Force / Difference of Potential	$e = \frac{E}{v}$ = work ÷ quantity	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$
Resistance	$r = \frac{R}{v^2}$ = electro-motive force ÷ current	$L^{-1}T$
Capacity	$k = v^2K$ = quantity ÷ electro-motive force	L
Sp. Ind. Capacity	= quantity ÷ another quantity	a numeral
IV.—DERIVED MAGNETIC.		
Strength of Pole / Quantity of Magnetism	$m = \sqrt{\text{force} \times \text{distance}^2}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}$
Moment of a Magnet	ml = strength of pole × length of poles	$L^{\frac{5}{2}}M^{\frac{1}{2}}T^{-1}$
Intensity of Magnetisation	I = moment of magnet ÷ volume	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$
Magnetic Potential	= work ÷ strength of pole	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$
V.—DERIVED ELECTRO-MAGNETIC.		
Current	$C = \frac{c}{v}$ = intensity of field × length	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$
Quantity	$Q = \frac{q}{v}$ = current × time $= CT$	$L^{\frac{1}{2}}M^{\frac{1}{2}}$
Electro-motive Force / Difference of Potential	$E = ev$ = work ÷ quantity	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}$
Resistance	$R = rv^2$ = electro-motive force ÷ current	LT^{-1}
Capacity	$K = \frac{k}{v^2}$ = quantity ÷ electro-motive force	$L^{-1}T^2$
Sp. Ind. Capacity	= displacement ÷ force	$L^{-2}T$
Self-induction, or "Quadrant"	$L_s = \frac{ET}{C} = \frac{\text{energy}}{C^2} = \frac{\mathbf{H} \times (\text{length})^2}{C}$	L
Ratio of electro-magnetic to electro-static unit of quantity, $v = 3 \times 10^{10}$ centimetres per second approximately.		LT^{-1}

TABLE 30.

TABLE OF $160\pi^2\left(\frac{h}{\lambda}\right)^2$; FOR USE IN FINDING RADIATION RESISTANCES OF ANTENNÆ.

(NOTE.—When a, the "form factor," is unity, as it nearly always is in commercial types of aerial, the following table, due to Zenneck, gives the radiation resistance directly in ohms.)

h in metres.	Wave-length λ in metres.																			
	300	400	500	600	700	800	900	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500	7,000
10	1·755	0·987	0·632	0·439	0·332	0·247	0·195	0·158	0·0702	0·0395	0·0253	0·0175	0·0129	0·00987	0·00780	0·00632	0·00520	0·00439	0·00370	0·00332
15	3·95	2·22	1·42	0·987	0·725	0·555	0·439	0·355	0·158	0·088	0·0568	0·0395	0·0290	0·0222	0·0176	0·0142	0·0117	0·00987	0·0084	0·00725
20	7·02	3·95	2·53	1·75	1·29	0·987	0·780	0·632	0·281	0·158	0·1010	0·0702	0·0516	0·0395	0·0312	0·0253	0·0209	0·0175	0·0149	0·0129
25	11·00	6·17	3·95	2·74	2·01	1·54	1·22	0·987	0·439	0·247	0·1580	0·1100	0·0806	0·0617	0·0487	0·0395	0·0326	0·0274	0·0234	0·0210
30	15·8	8·9	5·68	3·95	2·90	2·22	1·75	1·42	0·634	0·355	0·227	0·158	0·116	0·089	0·070	0·057	0·047	0·0395	0·0336	0·0290
35	21·5	12·1	7·74	5·37	3·95	3·02	2·39	1·93	0·860	0·484	0·309	0·215	0·158	0·121	0·095	0·077	0·064	0·0537	0·0458	0·0395
40	28·1	15·8	10·1	7·02	5·16	3·95	3·12	2·53	1·12	0·632	0·404	0·281	0·206	0·158	0·125	0·101	0·084	0·0702	0·0598	0·0516
45	35·5	20·0	12·8	8·88	6·53	5·00	3·95	3·20	1·42	0·800	0·512	0·355	0·261	0·200	0·158	0·128	0·106	0·0888	0·0757	0·0653
50	43·9	24·7	15·8	11·00	8·06	6·17	4·87	3·95	1·75	0·987	0·632	0·439	0·322	0·247	0·195	0·158	0·130	0·1100	0·0934	0·0806
55	53·1	9·8	19·1	13·3	9·8	7·46	5·90	4·78	2·12	1·19	0·76	0·531	0·390	0·298	0·236	0·191	0·158	0·133	0·113	0·098
60	63·2	35·5	22·7	15·8	11·6	8·88	7·02	5·68	2·53	1·42	0·91	0·632	0·464	0·355	0·281	0·227	0·188	0·158	0·134	0·116
65	74·1	41·7	26·7	18·5	13·6	10·4	8·24	6·67	2·96	1·67	1·07	0·741	0·544	0·417	0·329	0·267	0·221	0·185	0·158	0·136
70	86·0	48·4	30·9	21·5	15·8	12·1	9·55	7·74	3·44	1·93	1·24	0·860	0·631	0·484	0·382	0·309	0·256	0·215	0·183	0·158
75	98·7	55·4	35·5	24·7	18·1	13·9	11·00	8·88	3·95	2·22	1·42	0·987	0·725	0·554	0·439	0·355	0·294	0·247	0·210	0·181
80	—	63·2	40·4	28·1	20·6	15·8	12·5	10·1	4·49	2·53	1·62	1·12	0·83	0·632	0·499	0·404	0·334	0·281	0·239	0·206
85	—	71·3	45·6	31·7	23·3	17·8	14·1	11·4	5·07	2·85	1·83	1·27	0·93	0·713	0·563	0·456	0·377	0·317	0·270	0·233
90	—	80·0	51·2	35·5	26·1	20·0	15·8	12·8	5·68	3·20	2·05	1·42	1·04	0·800	0·632	0·512	0·423	0·355	0·303	0·261
95	—	80·1	57·0	39·6	29·1	22·3	17·6	14·2	6·33	3·56	2·28	1·58	1·16	0·891	0·704	0·570	0·471	0·396	0·337	0·291
100	—	98·7	63·2	43·9	32·2	24·7	19·5	15·8	7·02	3·95	2·53	1·75	1·29	0·987	0·780	0·632	0·522	0·439	0·374	0·322
110	—	—	76·4	53·1	39·0	29·8	23·6	19·1	8·49	4·78	3·06	2·12	1·56	1·19	0·94	0·76	0·63	0·531	0·452	0·390
120	—	—	90·9	63·2	46·4	35·5	28·1	22·7	10·1	5·68	3·64	2·53	1·86	1·42	1·12	0·91	0·75	0·632	0·538	0·464
130	—	—	—	74·1	54·5	41·7	32·9	26·7	11·9	6·67	4·27	2·96	2·18	1·67	1·32	1·07	0·88	0·741	0·631	0·545
140	—	—	—	86·0	63·2	48·4	38·2	30·9	13·8	7·74	4·95	3·44	2·53	1·93	1·53	1·24	1·02	0·860	0·732	0 632
150	—	—	—	98·7	72·5	55·4	43·9	35·5	15·8	8·88	5·68	3·95	2·90	2·22	1·76	1·42	1·17	0·987	0·840	0·725
160	—	—	—	—	82·5	63·2	49·9	40·4	18·0	10·1	6·47	4·49	3·30	2·53	2·00	1·62	1·34	1·12	0·96	0·83
170	—	—	—	—	93·1	71·3	56·3	45·6	20·3	11·4	7·30	5·07	3·72	2·85	2·25	1·83	1·51	1·27	1·05	0·93
180	—	—	—	—	—	80·0	63·2	51·2	22·7	12·8	8·19	5·68	4·18	3·20	2·53	2·05	1·69	1·42	1·21	1 04
190	—	—	—	—	—	89·1	70·4	57·0	25·3	14·2	9·12	6·33	4·65	3·56	2·81	2·28	1·88	1·58	1·35	1·16
200	—	—	—	—	—	98·7	78·0	63·2	28·1	15·8	10·10	7·02	5·16	3·95	3·12	2·53	2·09	1·75	1·49	1·29

TABLE 31.

TABLE OF Bd × 10^{10} FOR USE IN CALCULATING CORONA VOLTAGES.

Nearest S.W.G.	r.	r'.	Bd × 10^{10}.
(25)	0·01	0·012	317
(19)	0·02	0·026	308
16—17	0·03	0·041	299
(14)	0·04	0·055	289
12	0·05	0·068	278
11	0·06	0·082	265
9	0·07	0·098	250
(8)	0·08	0·118	226
7	0·09	0·143	195
5	0·10	0·164	172
4—5	0·11	0·179	170
4	0·12	0·190	Constant.
3	0·13	0·20	,,
2	0·14	0·21	,,
(1)	0·15	0·22	,,
1/0	0·16	0·23	,,
2/0	0·17	0·24	,,
3/0	0·18	0·25	,,
3/0—4/0	0·19	0·26	,,
(4/0)	0·20	0·27	,,

Wire gauges in brackets are of the exact radius r given in the table.

TABLE 32.

TABLE SHOWING THE DEPTH x cms. AT WHICH THE CURRENT VALUE IS $\frac{1}{100}$th OF THE SURFACE VALUE.

f cycles per sec.	λ metres.	x cms.
10^8	3	0·0029
5×10^7	6	0·0042
10^7	30	0·0093
5×10^6	60	0·0131
10^6	300	0·0293
5×10^5	600	0·0415
4×10^5	750	0·0463
3×10^5	1,000	0·0535
2×10^5	1,500	0·0656
$1·5 \times 10^5$	2,000	0·0757
10^5	3,000	0·0928
$7·5 \times 10^4$	4,000	0·1070
6×10^4	5,000	0·1196
5×10^4	6,000	0·1311
4×10^4	7,500	0·1465
3×10^4	10,000	0·1691
2×10^4	15,000	0·2070
$1·5 \times 10^4$	20,000	0·2395
10^4	30,000	0·2930

TABLE 33.

TABLE OF AERIAL FORM FACTORS α.

$$\alpha = 0·637\left(1 + \frac{L}{h}\right)\sin\left(\frac{h}{h+L}\right)90°.$$

$\frac{L}{h}$.	α.	$\frac{L}{h}$.	α.
0·0	0·639	1·5	0·940
0·1	0·696	2·0	0·958
0·2	0·741	3·0	0·979
0·3	0·777	4·0	0·987
0·4	0·806	5·0	0·993
0·5	0·830	6·0	0·996
0·6	0·850	7·0	0·998
0·7	0·867	8·0	0·999
0·8	0·881	9·0	0·999
0·9	0·893	10·0	1·000
1·0	0·904	100·0	1·000

SECTION III

EXAMPLE 1 (Formula par. 5).—Find the capacity of a plate glass condenser having 11 metal sheets, each 40 × 20 cms. for electrodes (5 to one pole, 6 to the other pole). Thickness of dielectric = 1 cm. Take S.I.C. = 8.

A = area of working sides of plates connected to one pole
= 5 × 2 (40 × 20) = 8,000 sq. cms.

$$\therefore K = \frac{A \cdot k}{11{\cdot}31 \times 10^6 d} = \frac{8{,}000 \times 8}{11{\cdot}31 \times 10^6 \times 1} = 0{\cdot}005658 \text{ mfd.}$$

EXAMPLE 2 (Formula par. 5).—Find the capacity per foot of span for an aerial of 12 wires 300 cms. apart and at a mean height of 101·5 ft. Length of span 900 metres. Radius of wire 0·3 cm.

$$\therefore \quad \frac{d}{r} = 1{,}000 \text{ (d and r in cms.)}$$

and $$\frac{l}{d} = 300 \text{ (d and l in metres).}$$

By interpolation from Table 7, E is 2·75 when $\dfrac{l}{2h} = \dfrac{900}{203}$ or 4·42.

From Table 8, B is 13·58 for $n = 12$.

Whence $$K' = \frac{17 \times 12}{12\left(\log_e 300 - 0{\cdot}31 - \dfrac{2{\cdot}75}{2}\right) + \log_e 1{,}000 - 13{\cdot}58}$$

$$= \frac{17 \times 12}{12\,(5{\cdot}70 - 0{\cdot}31 - 1{\cdot}37) + 6{\cdot}91 - 13{\cdot}58}$$

$$= \frac{204}{48{\cdot}2 - 6{\cdot}67} = 4{\cdot}91 \text{ micro-micro-farads per foot of span.}$$

EXAMPLE 3A (Lorenz's eqn.; Formula par. 7).—A long cylindrical inductance coil is wound with No. 16 S.W.G. wire with a spacing for 5 turns per cm.

The overall breadth of coil b = 15 cms.
Radius of mean turn a = 5 cms.
Turns n = 75.

Using Lorenz's equation

$$L_s = an^2Q,$$

it will be found that $Q = 17{\cdot}624$, for $\dfrac{2a}{b} = 1{\cdot}5$ (from Table 9).

$$L_s = 5(75)^2\ 17{\cdot}624 = 496{,}000 \text{ cms.}$$

This requires correcting by the formula for ΔL.

From wire Tables 15, the diameter of this wire is 0·1626 cm., and from the spacing the "effective" insulation diameter is $D = 0{\cdot}2$ cm.*

$$\frac{d}{D} = 0{\cdot}813 \text{ whence } A = + {\cdot}3500, \text{ Table 11.}$$

$$n = \quad 75 \quad ,, \quad B = + {\cdot}3249, \text{ Table 12.}$$

$$\Delta L = 4\pi 5 \times 75\ (+ {\cdot}6749)$$

$$= 3182.$$

True $\quad L = L_s - \Delta L = 496{,}000 - 3182$

$$= 492{,}820 \text{ cms. nearly.}$$

EXAMPLE 3B (Rayleigh; Formula par. 7).—A short cylindrical inductance coil has

breadth $b = 2$ cms.; $n = 10$.

radius $a = 20$ cms.; $d = 0{\cdot}18$ cm.; $D = 0{\cdot}2$ cm.

Determine its true inductance.

Using Rayleigh's equation

$$L_s = 4\pi a n^2 X.$$

From Table 10, $X = 3{\cdot}886$, for $\frac{a}{b} = 10$.

$$\therefore\ L_s = 4\pi 20 \times 100 \times 3{\cdot}886 = 97{,}700 \text{ cms.}$$

for the corrections A and B:—

$$\frac{D}{d} = 0{\cdot}9,\ \therefore\ A = + {\cdot}4515 \text{ from Table 11.}$$

$$n = 10,\ \therefore\ B = + {\cdot}2664 \quad ,, \quad 12.$$

$$\Delta L = 4\pi a n\ (A + B).$$

$$= 4\pi 20 \times 10\ (0{\cdot}7179) = 1{,}804.$$

True $\quad L = L_s - \Delta L = 97{,}700 - 1{,}804$

$$= 95{,}900 \text{ cms. approx.}$$

* NOTE.—D in all cases is the diameter over the insulation (either solid covering or air spacing) of turns.

Thus a bare wire 0·1 cm. diam. ($d = 0{\cdot}1$).
wound 10 turns per cm. $D = 0{\cdot}1$
,, 5 ,, ,, $D = 0{\cdot}2$
,, 2 ,, ,, $D = 0{\cdot}5$

and so on, irrespective of the covering material.

EXAMPLE 4 (Stefan; Formula par. 7).—A toroidal or flat spiral coil (pancake coil) of five turns, has the following dimensions. Find its true inductance.

Depth of spiral windings $c = 5$ cms.
Radius of mean turn $a = 20$ cms.
Axial breadth of coil $b = 0{\cdot}5$ cm.

(The coil being only one wire thick axially $b = d = 0{\cdot}5$ cm.)

For $\dfrac{b}{c} = \dfrac{0{\cdot}5}{5{\cdot}0} = 0{\cdot}1$. Table 13 gives $y_1 = 0{\cdot}59243$ and $y_2 = 0{\cdot}1325$.

$$L_u = 4\pi a n^2 \left[\left(1 + \frac{3b^2 + c^2}{96a^2}\right)\log_e \frac{8a}{\sqrt{b^2 + c^2}} - y_1 + \frac{b^2}{16a^2}\cdot y_2\right] \text{cms.}$$

$$= 4\pi 20 \times 5^2 \left[\left(1 + \frac{0{\cdot}75 + 25}{38{,}400}\right)\log_e \frac{160}{\sqrt{(\cdot 25 + 25)}} - \cdot 59243 + \frac{\cdot 25}{6{,}400} \times 0{\cdot}1325\right].$$

$= 6{,}283\ [\log_e 3{\cdot}185 - 0{\cdot}59243 + < \cdot 000005]$.
$= 6{,}283\ [1{\cdot}1584 - 0{\cdot}59243]$.
$= 3{,}556$ cms.

Corrections must be applied by $\Delta' L$.

Now $d = 0{\cdot}5$ cm., and with 5 turns in 5 cms. of radial depth D must be 1 cm.

Whence $$\frac{D}{d} = 2.$$

E_1 from Table 13, for $n = 5$ is $0{\cdot}01105$.

$$\Delta' L = 4\pi a n \left(\log_e \frac{D}{d} + 0{\cdot}13806 + E_1\right) \text{cms.}$$

$= 4\pi 20 \times 5\ (\log_e 2 + 0{\cdot}13806 + 0{\cdot}01105)$
$= 1{,}256{\cdot}6\ (0{\cdot}6932 + 0{\cdot}14911) = 1{,}059$ cms.

True $L = L_u + \Delta' L = 3{,}556 + 1{,}059 = 4{,}615$ cms.

EXAMPLE 5 (Formula, par. 8).—Calculate the mutual inductance between two coils; each wound with wire at 20 turns per cm.

	1st Coil.		2nd Coil.
Radius $= A$	$= 10$ cms.	$a =$	8 cms.
Breadth $= b_1$	$= 12{\cdot}5$,,	$b_2 =$	10 ,,
No. of turns $= n_1$	$= 250$,,	$n_2 =$	200 ,,
$g_1 = 0{\cdot}2887 b_1$	$= 3{\cdot}60$,,	$g_1 =$	$2{\cdot}90$,,

Distance between centres of coils $d = 27{\cdot}5$,,

Distance between P and $R = 26{\cdot}8$ cms.
P and $Q = 34{\cdot}0$,,
Q and $R = 21{\cdot}0$,,
Q and $S = 28{\cdot}2$,,

For Q and R

$$\frac{r_2}{r_1} = \frac{\sqrt{(10-8)^2 + (21)^2}}{\sqrt{(10+8)^2 + (21)^2}} = \sqrt{\frac{445}{765}} = 0{\cdot}762$$

and similarly for P and R $\frac{r_2}{r_1} = 0{\cdot}833$

,, ,, ,, P and S $\frac{r_2}{r_1} = 0{\cdot}885$

,, ,, ,, Q and S $\frac{r_2}{r_1} = 0{\cdot}845$

From Table 14 for P and R $\gamma = 0\ 550$
,, ,, ,, P and S $\gamma = 0{\cdot}304$
,, ,, ,, Q and R $\gamma = 0{\cdot}970$
,, ,, ,, Q and S $\gamma = 0{\cdot}485$
Mean γ from above $= 0{\cdot}577$

Whence $M = 0{\cdot}577\sqrt{10 \times 8} \times 200 \times 250$
$= 258{,}000$ cms.

(The above example is taken out of W. H. Nottage's article in the *W.W.*, p. 526, 1915.)

Example 6 (Equation, par. 9).—On plotting the complete double wave-tuning curve (or by measuring directly the wave-lengths of its two peaks) it is found that

$$\lambda'' = 1{,}250 \text{ metres}$$
$$\lambda' = 1{,}150 \text{ metres}$$

The natural wave-length λ being 1,200 metres, find the percentage coupling.

(i.) Using Table 20 we find for $\frac{\lambda''}{\lambda'} = 1{\cdot}087$ that the percentage coupling lies between 7·86 and 8·60. By interpolation the value is about 8·30,

or (ii.) Using Table 20, for $\frac{\lambda''}{\lambda} = 1{\cdot}041$, $K' = 8{\cdot}37$,

or again (iii.) ,, ,, ,, $\frac{\lambda'}{\lambda} = 0{\cdot}958_3$, $K' = 8{\cdot}24$.

Thus lying on each side of the value found by taking the value for $\frac{\lambda''}{\lambda'}$. This is probably explained by the disturbance produced by the wave-measuring instrument on the separated circuits, or to inaccuracies in determining λ.

EXAMPLE 7 (Formula, par. 21).—The absorption constant α in this formula has different values assigned to it by different authorities.

The general opinion seems to be that 0·0015 to 0·0019 represent the average limits as found experimentally; though in, wirelessly speaking, "opaque" zones a higher figure still would be necessary.

Assume that I_2 must be 30×10^{-6} amps. for clear signals.

Wave-length used 10,000 metres (10 kms.) $h_1 = h_2 = 100$ metres or 0·1 km.

Distance apart of stations $d = 3{,}000$ kms.

Find the necessary transmitting current assuming a dissipation constant $\alpha = 0{\cdot}0018$.

$$I_1 = I_2 \frac{\lambda d}{4{\cdot}25 h_1 h_2} \epsilon^{+\frac{\alpha d}{\sqrt{\lambda}}}.$$

$$= \frac{30 \times 10^{-6} \times 10 \times 3{,}000}{4{\cdot}25 \times 0{\cdot}1 \times 0{\cdot}1} \epsilon^{\frac{0{\cdot}0018 \times 3{,}000}{\sqrt{10}}}.$$

$$= 21{\cdot}18\, \epsilon^{1{\cdot}707}$$

$$= 21{\cdot}18 \times 5{\cdot}349$$

$$= 113 \text{ amps.}$$

EXAMPLE 7A.—Two similar cruisers have aerials 50 metres high; and employ a wave-length of 1,200 metres.

Find the necessary transmitting aerial current for them to communicate when 500 miles apart.

(Take 40 micro-amps. as the current required to be received for strong signals.)

Formula par. 7, $$I_1 = I_2 \frac{\lambda d}{4{\cdot}25 h_1 h_2} \cdot \epsilon^{\frac{0{\cdot}0019 d}{\sqrt{\lambda}}} \text{ amps.}$$

The high value of the constant in the index of the exponential is taken on account of the short wave-length, with which there is greater absorption than with long wave-lengths.

$$d = 500 \times 1{\cdot}609 = 805 \text{ kms.}$$
$$h_1 = h_2 = 0{\cdot}05 \text{ km. (similar aerials)}$$
$$\lambda = 1{\cdot}2 \text{ kms.}$$
$$I_2 = 40 \times 10^{-6} \text{ amps.}$$
$$I_1 = 40 \times 10^{-6} \frac{1{\cdot}2 \times 805}{4{\cdot}25 \times 0{\cdot}05 \times 0{\cdot}05} \cdot \epsilon^{\frac{0{\cdot}0019 \times 805}{\sqrt{1{\cdot}2}}}$$
$$= 3{\cdot}635 \,.\, \epsilon^{1{\cdot}396}$$
$$= 3{\cdot}635 \times 4{\cdot}04 = 14{\cdot}7 \text{ amps.}$$

In the above example, taking 0·0015 for the constant in the exponential; and assuming an I_s of 20 amps.; find the strength of signals at a distance of 1,000 miles.

$$I_2 = I_1 \times 4{\cdot}25 \frac{h_1 h_2}{\lambda d} \epsilon^{\frac{-0{\cdot}0015 d}{\sqrt{\lambda}}}$$
$$= 20 \times 4{\cdot}25 \times \frac{0{\cdot}05 \times 0{\cdot}05}{1{\cdot}2 \times 805} \epsilon^{\frac{-0{\cdot}0015 \times 1{,}000 \times 1{\cdot}609}{\sqrt{1{\cdot}2}}}$$
$$= \frac{0{\cdot}00011}{\epsilon^{2{\cdot}202}} = \frac{0{\cdot}00011}{9{\cdot}04} = 0{\cdot}000012 \text{ amps., } i.e., \text{ 12 micro-amps.}$$

EXAMPLE 8 (Formula, par. 23).—It is required to find the distance over the great circle arc, between San Francisco, and Choishi (Japan).

San Francisco	$\theta =$	37°	44′	40″ N.
	$a =$	122°	24′	20″ W.
Choishi . .	$\theta =$	35°	44′	03″ N.
	$a =$	140°	51′	12″ E.

Hav. ϕ = hav. ((90° — θ) — (90° — θ')) + hav. (diff. long) sin 90 — θ sin 90° — θ'.

= hav. (diff. θ) + hav. (diff. a) sin 52° 15′ 20″ sin 54° 15′ 22″.

= hav. 2° 0′ 32″ + hav. 96° 44′ 28″ sin 52° 15′ 20″ sin 54° 15′ 22″.

= ·000307 + 0·558694 × 0·7907 × 0·8117.

= ·358889.

ϕ = 73° 36′ 26″.

whence $d = 60\,\phi = 60 \times 73{\cdot}608$.

$= 4{,}416\tfrac{1}{2}$ miles.

(Haversine Table 6.)

EXAMPLE 9.—Determine the probable value of the resistance decrement for the following oscillatory circuit.

Inductance	85,000 cms.
Wave-length	300 metres.
Frequency	10^6
Spark length	0·25 cm. zinc balls.
Length of wire used in circuit.	25 metres.
Size of wire No. 22 S.W.G., D.C.C.	3 strands in parallel.

Diam. d (per strand) = 0·7112 mm. (Table 15).

High frequency resistance per metre of single strand for 10^6 frequency = 0·128 ohm. (by interpolation from Table 18).

H.F. resistance of 25 metres of 3/22 (each strand D.C.C.).

$$= \frac{25 \times 0{\cdot}128}{3} = 1{\cdot}066 \text{ ohms.}$$

Spark resistance for above gap (Table 25) = 8·4 ohms.

Total H.F. resistance = 9·466 ohms.

$$\text{Resistance decrement } \delta_R = \frac{R'}{4nL} \text{ per half-period.}$$

$$= \frac{9{\cdot}466}{4 \times 10^6 \times 85{,}000 \times 10^{-9}}$$

$$= 0{\cdot}0278 \text{ per half-period.}$$

EXAMPLE 10.—*Centrifugal Force* (Equation par. 30).—The centrifugal force acting on a body rotating at a radius r feet at a given speed is

$$F = 0{\cdot}00034r\,(\text{R.P.M.})^2 \text{ times its mass.}$$

Example : A long radial tooth of a disc discharger weighs 6 ozs. The speed of disc is 3,000 R.P.M. Find the pull tending to strip it out of the disc. Its centre of mass may be taken as revolving on a 2-foot radius.

$$F = 0{\cdot}00034 \times 2 \times (3{,}000)^2 = 6{,}120 \text{ times its mass.}$$

$$\text{Pull} = 6{,}120 \times \frac{6}{16} \text{ lbs.}$$

$$= 2{,}295 \text{ lbs. or just over 1 ton.}$$

EXAMPLE 11 (Equation par. 10, Table 31).—*On the Radiation Resistance and Radiation Decrement of Aerials.*—The radiation of energy from an aerial affects the oscillations therein, as though the aerial was possessed of ohmic resistance; and the value of this "resistance" can be expressed as

$$R = 160\pi^2 \left(\frac{ah}{\lambda}\right) \text{ ohms.}$$

where h is the aerial height in metres
λ is the wave-length transmitted
and a is called the form factor of the aerial.

Aerial Form Factors.—A straight single vertical wire antenna, working as a "simple" aerial without added capacity or inductance, has a current distribution which can be approximately represented by a straight line having a maximum current value at the foot of the antenna and a zero current value at the top.

The form factor in this case would be $a = 0{\cdot}5$.

As soon as the top of the aerial is increased in size and therefore capacity, the law of current diminution from the foot to the top does not follow a straight line law, but follows more that of a constant + a sine law.

For pure sine law distribution of current $a = \dfrac{2}{\pi} = 0{\cdot}6366$.

Generally, however, not only is the aerial heavily loaded at the top with capacity, but, in addition, has a series inductance near the base, which latter, in conjunction with the capacity top tends to give a more or less uniform current distribution on the vertical portion. For such a uniform distribution the form factor $a = 1{\cdot}00$.

For most commercial types of aerial the form factor a will be quite near unity.

The above expression is

$$R = a^2 \left[160\pi^2\left(\frac{h}{\lambda}\right)^2\right] \text{ ohms.}$$

The values of the part in the square brackets is tabulated in Table 31, when (if a is taken as unity) it gives directly the radiation resistances for aerials of various heights and oscillating at various wave-lengths.

Example: Find the radiation resistance and radiation decrement for the following case :—

Ship's aerial $h = 50$ metres

$\lambda = 600$ metres

whence $n = \frac{v}{\lambda} = \frac{3 \times 10^8}{600} = 500{,}000$. Take $L = 80{,}000$ cms. (assumed).

Take form factor $a = 1{\cdot}00$.
Radiation resistance (from Table 31) for $h = 50$ and $\lambda = 600$ is 11·0 ohms.

$$\text{Radiation decrement } \delta = \frac{R'}{4nL} = \frac{11{\cdot}0}{4 \times 500{,}000 \times 80{,}000 \times 10^{-9}}$$

$$= 0{\cdot}0687$$

say 0·07 per semi-period.

Example 12.—*On the Determination of the K.W. and Aerial Capacity for a given Station.*—The following must be known :—

Spark train frequency $N = 600$ say
Log. dec. of station . $\delta = 0{\cdot}05$
Aerial current . . $I_s = 100$ amps. say
Wave-length . . $\lambda = 6{,}000$ metres

$$\text{whence} \quad n = \frac{3 \times 10^8}{6{,}000} = 50{,}000 \text{ per sec.}$$

$$p = 2\pi n = 314{,}160.$$

It is necessary to determine the energy per spark in the aerial circuit, and to do this the aerial capacity and charging voltage must be known. There are an infinite number of aerial capacities and charging voltages that would enable an aerial current of 100 amps. to be obtained ; but by an inspection of a few parallel examples it will be noticed that a few only fall within the bounds of practicable engineering.

A tabular construction is a clear way of arranging the calculations for the purpose of choosing corresponding values of the several inter-related functions of an aerial.

From the following example it will be clear how inadmissible is an aerial capacity of 0·001 mfd. on account of excessive voltage and power required in its operation.

Similarly, an aerial capacity of 0·03 mfd. would be on the high side, for the aerial voltages and power are needlessly low for the case in hand.

$K_2 = 0{\cdot}001$ mfd.	0·005 mfd.	0·008 mfd.	0·01 mfd.	0·015 mfd.	0·02 mfd.	0·03 mfd.
$V_{2\text{RMS}} = \dfrac{I_{\text{RMS}}}{K_2 \cdot p} = \dfrac{100}{0{\cdot}001 \times 10^{-6} \times 314{,}160}$ $= 318{,}300$ volts	63,660 volts	39,800 volts	31,830 volts	21,210 volts	15,960 volts	10,610 volts
$V_{2\max} = V_{2\text{RMS}}\sqrt{\dfrac{8n\delta}{N}}$ $= V_{2\text{RMS}} \times 5{\cdot}772$ $= 1{,}838{,}000$ volts.	367,600 volts	229,700 volts	183,800 volts	122,500 volts	92,300 volts	61,200 volts
Energy per spark :— $= \frac{1}{2}K_2 V_{2\max}^2$ $= \frac{1}{2} \times 0{\cdot}001 \times 10^{-6} \times (1{,}838{,}000)^2$ $= 1{,}688$ watt-secs.	337·5 watt-secs.	210·8 watt-secs.	168·8 watt-secs.	112·6 watt-secs.	85·0 watt-secs.	56·6 watt-secs.
K.W. at 600 spark trains per sec. $= \dfrac{1{,}688 \times 600}{1{,}000}$ $= 1{,}012{\cdot}5$ K.W.	202·5 K.W.	126·5 K.W.	101·2 K.W.	67·5 K.W.	51 K.W.	34 K.W.

It will be seen that as the aerial capacity goes up the K.W. required by the aerial go down, so that a final decision cannot be made on a voltage basis alone. For instance, in some localities power might be abnormally expensive and land very cheap, in which case a higher aerial capacity would be chosen than in a place where power was very cheap and land more expensive. In any case a large aerial is an expensive structure and its dimensions must be carefully chosen so that the best design may be arrived at for the particular station in hand.

EXAMPLE 13.—*An interesting example on the number of watts received by an aerial.*

Spark train frequency 400 ~ per sec.

Log. dec. $\delta = 0{\cdot}08$ per semi period

Wave-length $\lambda = 600$ metres

whence oscillation frequency = 500,000 per sec.
Received current I_R = 40 micro-amps.
Inductance in aerial = 100,000 cms.
Capacity of aerial = 0·001 mfd.

$$I_{max} = I_{RMS} \sqrt{\frac{8n\delta}{N}}$$

$$= 40 \times 10^{-6} \sqrt{\frac{8 \times 500,000 \times 0{\cdot}08}{400}}$$

$$= 1,131 \times 10^{-6} \text{ amps.}$$

Energy per train $= \frac{1}{2}L \,.\, I^2_{max}$ (L in henries).
$= \frac{1}{2} \times 0{\cdot}0001 \times (1{,}131^2) \times 10^{-12}$
$= 64 \times 10^{-12}$ watt-secs. per train at 400 trains per second.

Received watts in aerial $= 64 \times 10^{-12} \times 400$
$= 0{\cdot}0256 \times 10^{-6}$ watts
or $= 0{\cdot}0256$ micro-watt.

Since the energy per train also $= \frac{1}{2}KV^2_{max}$ (K in farads), the receiver maximum voltage is

$$V_{1max} = \sqrt{\frac{2 \times 64 \times 10^{-12}}{0{\cdot}001 \times 10^{-6}}} = 0{\cdot}358 \text{ volt.}$$

$$\text{and } V_{RMS} = \frac{I_{RMS}}{K_1 p} = \frac{40 \times 10^{-6}}{0{\cdot}001 \times 10^{-6} \times 2\pi \times 500,000}$$

$$= 0{\cdot}01272 \text{ volt.}$$

Thus true watts $= 0{\cdot}0256 \times 10^{-6}$
and apparent watts $= 40 \times 10^{-6} \times 0{\cdot}01275$
$= 0{\cdot}5088 \times 10^{-6}$ volt-amps.

It should be noted that the "true watts" obtained in this calculation assumes that the effect is spread evenly over a considerable time. In other words it takes no account of the fact that this number of watts comes in at a very much higher value during each wave-train; and the sound-producing effect is to a great extent determined by the rate at which energy is coming in, over the period of the wave-train. It is obvious that no sound-producing effect is exerted between wave-trains.

Considering the wave-train as non-effective after 100 half oscillations

$$m = \frac{4{\cdot}605 + \delta}{\delta} \text{ where } \delta \text{ is the log. dec. per half period.}$$
$$= \frac{4{\cdot}685}{0{\cdot}08}$$
$$= 58{\cdot}5$$

Thus the wave-train may be said to be over in 29 to 30 cycles.

Hence, duration of each train $= \dfrac{30 \times 1}{500{,}000} = 0{\cdot}00006$ sec.

Watt seconds per train $= 64 \times 10^{-12}$ Joules.

Watts expended during one train of waves arriving

$$= \frac{64 \times 10^{-12}}{0{\cdot}00006}$$
$$= 1{\cdot}066 \times 10^{-6} \text{ watts.}$$
$$= 1{\cdot}066 \text{ micro-watts.}$$

EXAMPLE 14.—*Maximum and R.M.S. Currents flowing in Transmitting Station Circuits.—Aerial Earth Circuit.*—A station has an aerial current of 100 amps. R.M.S. and a capacity of 0·015 mfd. ($\lambda = 6{,}000$ m.) Find the maximum value ($I_{2\max}$) of the aerial current oscillation.

$$I_{2\,\max}^{2} = \frac{K_2}{L_2}(V_{2\max})^2.$$

K_2 and L_2 being in farads and henries.

Now $V_{2\max}$ was found to be 122,500 volts in Example 12.

$$L_2 = \frac{\lambda^2}{(59{\cdot}6)^2 K_{2\text{mfds.}}} = \frac{(6{,}000)^2}{(59{\cdot}6)^2\, 0{\cdot}015} = 676{,}000 \text{ cms. or } 676{,}000 \times 10^{-9}$$
henries.

$$I_{2\max} = \sqrt{\frac{0{\cdot}015 \times 10^{-6}}{676{,}000 \times 10^{-9}}} \times 122{,}500.$$
$$= 575 \text{ amps.}$$

Primary Coupled Circuit.—Assume transformer maximum voltage $= 40{,}000$ volts. Determine the maximum and R.M.S. currents in this circuit, taking $K_1 = 0{\cdot}2$ mfd.

$$L_1 = \frac{\lambda^2}{(59{\cdot}6)^2 K_1} = \frac{6{,}000^2}{(59{\cdot}6)^2 \times 0{\cdot}2} = 50{,}350 \text{ cms.}$$

$$I_{1\,\mathrm{max}}^2 = \frac{K_1}{L_1} V_{1\,\mathrm{max}}^2, \ K \text{ being in farads and } L \text{ in henries.}$$

$$I_{1\mathrm{max}} = \sqrt{\frac{0{\cdot}2 \times 10^{-6}}{50{,}350 \times 10^{-9}}} \times 40{,}000$$
$$= 2{,}525 \text{ amps.}$$

$$I_{1\mathrm{RMS}} = I_{1\mathrm{max}} \sqrt{\frac{N}{8n\delta}}.$$
$$= 2{,}525 \sqrt{\frac{600}{8 \times 50{,}000 \times 0{\cdot}05}}$$
$$= 437 \text{ amps. R.M.S.}$$

It is this current which is taken when designing the size of conductor for the circuits and inductances carrying it.

NOTES ON EXAMPLE 15.—*The Tone Wheel.*—This consists of a notched disc with a fine brush making contact with the projecting teeth. By running this disc at a steady speed, greater or less than that corresponding to one contact per cycle, a low-frequency alternating current can be obtained of audible frequency.

Let $2X = T$, the time of one complete cycle of the high frequency current.

Let $X + \delta X =$ time of contact
$=$ time of interruption,

i.e., The speed of the disc is less than that corresponding to synchronism, and is $S - \delta s$ where S is the synchronous speed.

$$\frac{T}{2} = X = \frac{1}{S}.$$
$$\frac{T}{2} + \delta t = X + \delta X = \frac{1}{S - \delta s}. \quad \text{For a ``slow'' disc.}$$

Let T' be the time period of the resulting L.F. current

$$\frac{T'}{2} = X' = \frac{1}{S - (S - \delta s)} \text{ or } \frac{1}{(\delta + \delta s) - S} = \frac{1}{\delta s}.$$

Thus
$$\frac{T'}{T} = \frac{S}{\delta s}.$$

Hence for a given value of the high frequency (*i.e.*, given S) the ratio of the two time periods depends solely on δs, the amount of asynchronism.

EXAMPLE 15.—

Let $\lambda = 10{,}000$ or $\sim\, = 30{,}000$

Let disc have 500 teeth

whence $S = 60$ revs. per sec. or 3,600 revs. per min.

Find what speed the disc must be run to generate a low-frequency current of 1,000 $\sim$.

$$\frac{T'}{T} = 30 = \frac{S}{\delta s}$$

$$\therefore\ \delta s = \frac{3{,}600}{30} = 120 \text{ R.P.M.}$$

This is the difference in speed between the disc speed and the synchronous speed of S.

Thus the disc can be run at either 3,480 or 3,720 R.P.M.

Example on Selectivity of Tone Wheel.—Let two stations having frequencies of 40,000 and 42,000 respectively be working simultaneously.

Let the tone wheel speed correspond to a frequency of 39,000.

The first station gives

$$\frac{T'}{T} = \frac{40}{1}$$

whence the low frequency = 1,000.

The second station gives

$$\frac{T'}{T} = \frac{42}{3} = 14$$

whence the low frequency = 3,000.

This example illustrates the fact that stations whose frequencies are nearly equal, do not produce low-frequency currents of anything approaching equality.

NOTES ON EXAMPLE 16.—*The Poulsen Tikker.*—The principle of this devise is dealt with in text-books. Briefly it consists of a vibrating contact device, by means of which a closed receiving oscillatory circuit condenser is switched on to a telephone by each vibration. The energy accumulated during the period that the vibratory contact is "open" is suddenly released into the telephone circuit. As the vibration is of audible frequency the telephone diaphragm emits a note corresponding to this contact frequency.

Example 16 *on Tikker Working.*—
Let Tikker frequency of contact = 400 per sec., $\lambda = 300$ m., high frequency = 10^6 per sec.
Let duration of a dash be 0·5 sec.

$$\text{Number of waves} = \frac{10^6}{2} = 500{,}000.$$

Energy released due to each contact of tikker is that due to $\frac{10^6}{400}$ = 2,500 waves and this is released each time the contact closes; which is 200 times for a dash, on the above assumptions.

This is comparable with there being 2,500 oscillations per "wave-train" if it was a spark sender. Usually the number of waves per train in a spark system is not much over 200 to 300.

NOTES ON EXAMPLE 17.—*Corona Effect.*—Two conductors when at a high difference of potential, will under certain conditions produce a corona or silent electric glow discharge.

Such a discharge if very pronounced produces a serious loss of energy, hence it is desirable to be able to design circuits carrying high voltage currents so that no such corona occurs.

The absolute temperature of the air, the barometric height, the size and spacing of the conductors determines the p.d. that will start a corona.

Let h = barometric height in inches.
T = absolute temperature in degrees Fahrenheit ($T = t + 459{\cdot}2$) where t is the thermometer reading in degrees Farenheit.
r' = effective radius of conductor (see Table 31), *i.e.*, the radius of the conductor + the depth of the weakest zone of atmosphere surrounding the conductor.
r = radius of conductor in inches.
l = distance apart of conductors in inches.

$$\text{Then} \qquad E_{\max} = \frac{17{\cdot}9h}{T}\, 2{\cdot}055\, r' \log_{10}\left(\frac{l}{r}\right) \times Bd \times 10^{13} \text{ volts.}$$

$$\text{or} \qquad = 36{,}800\, \frac{hr'}{T} \log_{10}\left(\frac{l}{r}\right) \times Bd \times 10^{10} \text{ volts.}$$

A simplification takes place if one takes air temperature 60° F. and barometer 30·00″, again using $Bd \times 10^{10}$ as this occurs in the tabulated values

$$E_{\max} = 2{,}125{\cdot}5\, r' \log_{10}\left(\frac{r}{l}\right) \times Bd \times 10^{10} \text{ volts approximately.}$$

The above formulæ are intended for similar parallel conductors between which the potential difference found from the expression is the maximum that can be applied without serious corona loss. For conductors such as a single aerial wire, with the earth's surface as the other conductor, the above can be used as a rough guide only.

$$E_{\max} = \frac{2\pi r'' Bd}{K} \text{ volts.}$$

where $K =$ farads per cm. length of wire

$r'' =$ radius of wire in cms.

This may be of use in certain cases where the capacity of an aerial wire is known, and the value of $E_{\max}$ for the wire is required.

EXAMPLE 17A.—A horn lightning arrester is placed at the lead-in terminal of a wireless transmitting station.

S.W.G. $= 1{\cdot}0$, *i.e.*, $r = 0{\cdot}15$ inches.

The rods are 4 inches apart at their nearest point. Taking the standard air conditions, what will be the maximum voltage that can be employed without a corona appearing.

$$\begin{aligned} E_{\max} &= 2{,}125 \times 0{\cdot}22 \times \log_{10}\left(\frac{4}{0{\cdot}15}\right) \times 170 \\ &= 79{,}500 \times 1{\cdot}4249 \\ &= 113{,}200 \text{ volts.} \end{aligned}$$

EXAMPLE 17B.—Inductances and connections in a certain station are made of ¾-inch copper tube. They approach within 3 feet of metallic structures in the station.

Find the corona voltage.

Take station air temperature 70° F., *i.e.*, 529° F. abs.

barometer reading 29·5″.

$$\begin{aligned} E_{\max} &= \frac{17{\cdot}9 \times 29{\cdot}5}{529} \times 2{\cdot}055\,(0{\cdot}375 + 0{\cdot}07) \times \log_{10}\left(\frac{36}{0{\cdot}375}\right) \times 170{,}000 \\ &= 307{,}000 \text{ volts.} \end{aligned}$$

NOTES ON EXAMPLE 18. *The Pull of an Iron Cored Solenoid on an Armature, for small Air Gaps.*—

Let Bg = Density in air gap in lines per sq. cm.
= $1{\cdot}257 \times$ amp. turns per cm. length of gap.
Ag = area of gap in sq. cms.
Then P = pull in kgrs.

$$P = \frac{Bg^2 Ag}{8\pi 981{,}000} \text{ kgrs.}$$

Inductance of solenoid

$$L = \frac{0{\cdot}707}{10^8} \frac{T\phi}{I} \text{ henries,}$$

where T = number of turns on solenoid
ϕ = toal flux = $Bg \times Ag$
I = magnetising current in amperes.

Current value, and hence pull at any time t, after closing the magnetising circuit

$$i = \frac{E}{R}\left(1 - \epsilon^{-\frac{Rt}{L}}\right).$$

where E = e.m.f. of source used for solenoid.
R = total circuit resistance in ohms, $\left(\frac{E}{R}\right)$ being the "steady" current of the circuit.
L = inductance in henries.
ϵ = base of Napierian logarithms.

EXAMPLE 18.—It is required to operate a certain high speed signalling key of short movement. The armature gap is 0·5 cm. The time available for obtaining a magnetis ng current to give the required minimum operating pull of 5 kgrs. is 0·005 sec. Propose a suitable solenoid to operate off a 20-volt. local battery.

Take Bg = 10,000 lines per sq. cm.

From equation for pull $Ag = \dfrac{P \times 8\pi \times 981{,}000}{Bg^2}$

$$= \frac{5 \times 8\pi \times 981{,}000}{(10{,}000)^2} = 1{\cdot}23 \text{ sq. cms.}$$

Ats. per cm. length of gap $= \dfrac{Bg}{1 \cdot 257} = 7{,}960.$

Ats. for above gap $= 3{,}980.$

Use a suitable wire for 5 amps.

Turns $= 796$ or say 800.

Inductance of solenoid $L = \dfrac{0 \cdot 707 \times 800 \times 10{,}000 \times 1 \cdot 232}{10^8 \times 5}$

$= 0 \cdot 01394$ henry.

The resistance of the coil would have to be found in design by trial and error. With a suitable arrangement $R = 2 \cdot 25$ ohms. Now the current after $t = 0 \cdot 005$ second must be 5 amps. or more.

$$i = \frac{20}{2 \cdot 25}\left(1 - \frac{1}{\epsilon^{\frac{2 \cdot 25 \times 0 \cdot 005}{0 \cdot 01394}}}\right) \text{ amps.}$$

$$= 8 \cdot 89 \left(1 - \frac{1}{\epsilon^{0 \cdot 898}}\right)$$

$$= 8 \cdot 89\,(1 - 0 \cdot 408)$$

$$= 5 \cdot 26 \text{ amps.}$$

NOTES ON ABACS AND EXAMPLES 19.—*On the determination of capacity, inductance, and wave-length of antennæ.*—(Abstracted from Dr. Eccles' article in the "Year Book of Wireless Telegraphy, 1916," pp. 616—624.)

Let L_o = equivalent inductance of antenna.

K_o = ,, capacity of antenna.

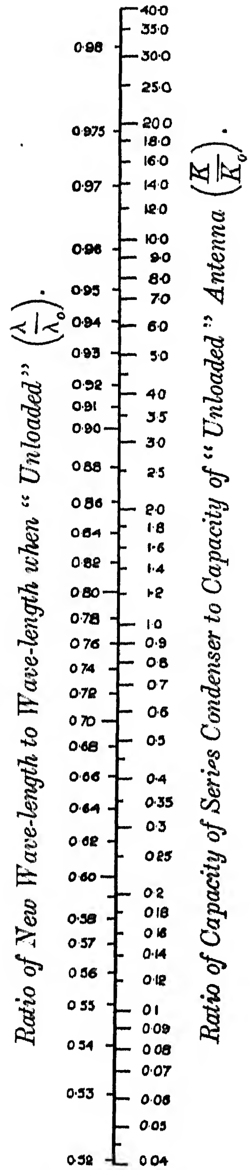
λ_o = "unloaded" or "natural" wave-length of antenna.

L and K = added inductances and capacities.

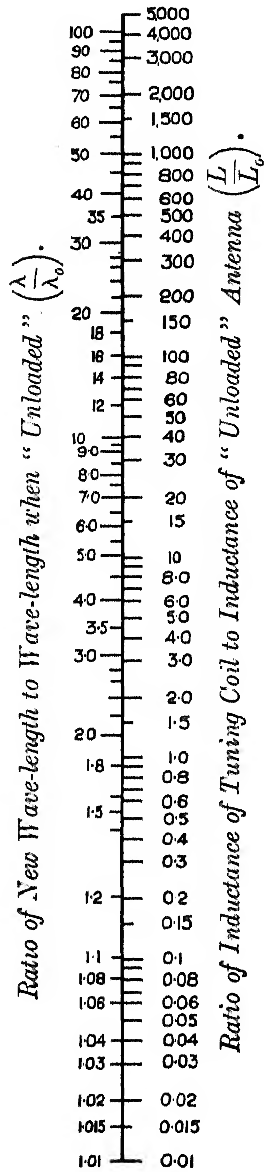
λ = wave-length resulting from the added L or K or both.

Use of Abacs.—(1) For any known ratio of new wave-length (λ) to wave-length when unloaded (λ_o), the corresponding ratio of capacity of added series condenser (K) to capacity of unloaded antenna (K_o) can be read off, or *vice versâ*.

(2) Abac 2 gives corresponding values of the two ratios of wave-length and inductance.


Ratio of New Wave-length to Wave-length when "Unloaded" $\left(\frac{\lambda}{\lambda_0}\right)$.
Ratio of Capacity of Series Condenser to Capacity of "Unloaded" Antenna $\left(\frac{K}{K_0}\right)$.
0·98
0·975
0·97
0·96
0·95
0·94
0·93
0·92
0·91
0·90
0·88
0·86
0·84
0·82
0·80
0·78
0·76
0·74
0·72
0·70
0·68
0·66
0·64
0·62
0·60
0·58
0·57
0·56
0·55
0·54
0·53
0·52
40·0
35·0
30·0
25·0
20·0
18·0
16·0
14·0
12·0
10·0
9·0
8·0
7·0
6·0
5·0
4·0
3·5
3·0
2·5
2·0
1·8
1·6
1·4
1·2
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·35
0·3
0·25
0·2
0·18
0·16
0·14
0·12
0·1
0·09
0·08
0·07
0·06
0·05
0·04

Abac 1.


Ratio of New Wave-length to Wave-length when "Unloaded" $\left(\frac{\lambda}{\lambda_0}\right)$.
Ratio of Inductance of Tuning Coil to Inductance of "Unloaded" Antenna $\left(\frac{L}{L_0}\right)$.
100
90
80
70
60
50
40
35
30
20
18
16
14
12
10
9·0
8·0
7·0
6·0
5·0
4·0
3·5
3·0
2·0
1·8
1·5
1·2
1·1
1·08
1·06
1·04
1·03
1·02
1·015
1·01
5,000
4,000
3,000
2,000
1,500
1,000
800
600
500
400
300
200
150
100
80
60
50
40
30
20
15
10
8·0
6·0
5·0
4·0
3·0
2·0
1·5
1·0
0·8
0·6
0·5
0·4
0·3
0·2
0·15
0·1
0·08
0·06
0·05
0·04
0·03
0·02
0·015
0·01

Abac 2.

(NOTE.—In the application of (1) and (2) it is assumed that only added capacity or inductance are present. In the following (3) to (5) both capacity and inductance are added together.)

(3) (4) (5) These are all similar, and give corresponding relations, of three ratios (inductance, capacity, and the resulting wave-length ratio), each abac dealing with a limited range of wave-length ratios

Knowing λ_o, L_o, and K_o it is required to find for a given added L and K what the resulting wave-length λ will be.

Find ratios $\frac{L}{L_o}$ and $\frac{K}{K_o}$.

Then with a straight-edge or black thread, join these two ratios, and find where the same straight line intersects the wave-length ratio curve.

This gives $\frac{\lambda}{\lambda_o}$ whence $\lambda =$ ratio found $\times \lambda_o$.

The third of the subsequent numerical worked examples illustrates the use of these abacs. Obviously other inter-relations can be found, knowing any two complete ratios, and a member of the third ratio.

Determination of λ_o, K_o, and L_o :—

(λ_o).—This is easily measured by means of a wave meter and buzzer, with a h.f. galvanometer in the antenna circuit, the wave meter being coupled to the antenna by the smallest possible coupling loop in the latter circuit. A simpler method consists of exciting the antenna across the break points of a buzzer and measuring λ_o by means of a loosely coupled wave meter.

(K_o).—Add a known capacity K in series with the antenna whose effective capacity is K_o to be found.

Measure the new wave-length λ.

Then $\frac{\lambda}{\lambda_o}$ if lying between 0·52 and 0·98 will be found in abac 1, opposite which $\frac{K}{K_o}$ will be found.

For example, let $\frac{\lambda}{\lambda_o} = 0{\cdot}76$ when K was 0·001 mfd.

$$\text{From abac 1 } \frac{K}{K_o} = 0{\cdot}9, \text{ whence } K_o = \frac{K}{0{\cdot}09} = 0{\cdot}0111 \text{ mfd.}$$

(L_o).—Add a known inductance L in series with the antenna whose effective inductance is L_o to be found.

Measure the new wave-length λ.

Then $\frac{\lambda}{\lambda_o}$ if lying between 1·01 and 100 will be found in abac 2, opposite which $\frac{L}{L_o}$ will be found.

For example, let $\frac{\lambda}{\lambda_o} = 1{\cdot}2$ when L was 40,000 cms.

From abac 2, $\frac{L}{L_o} = 0{\cdot}2$, whence $L_o = \frac{L}{0{\cdot}2} = 200{,}000$ cms.

Since $\frac{\lambda}{\lambda_o} = 0{\cdot}774$ when $K = K_o$ (abac 1)

and $\frac{\lambda}{\lambda_o} = 1{\cdot}84$ when $L = L_o$ (abac 2), it follows that a simple procedure can be arrived at for determining K_o and L_o as follows :—

(K_o).—Find such a value of K, which, when placed in series with the aerial, the wave-length λ is 0·774 times the natural wave-length λ_o. Then $K = K_o$.

That is, (i.) Find λ_o.
(ii.) Calculate what $\lambda = 0{\cdot}774\lambda_o$ is.
(iii.) Vary K till wave-length is λ.
(v.) Measure K so found, which is equal to K_o.

L_o.—Find such a value of L, which when placed in series with the aerial, gives a wave-length λ 1·84 times the natural wave-length λ_o. Then L so found $= L_o$.

That is, (i.) Find λ_o.
(ii.) Calculate what $\lambda = 1{\cdot}84\lambda_o$ is.
(iii.) Vary L till wave-length is λ.
(iv.) Measure or calculate L so found which is equal to L_o.

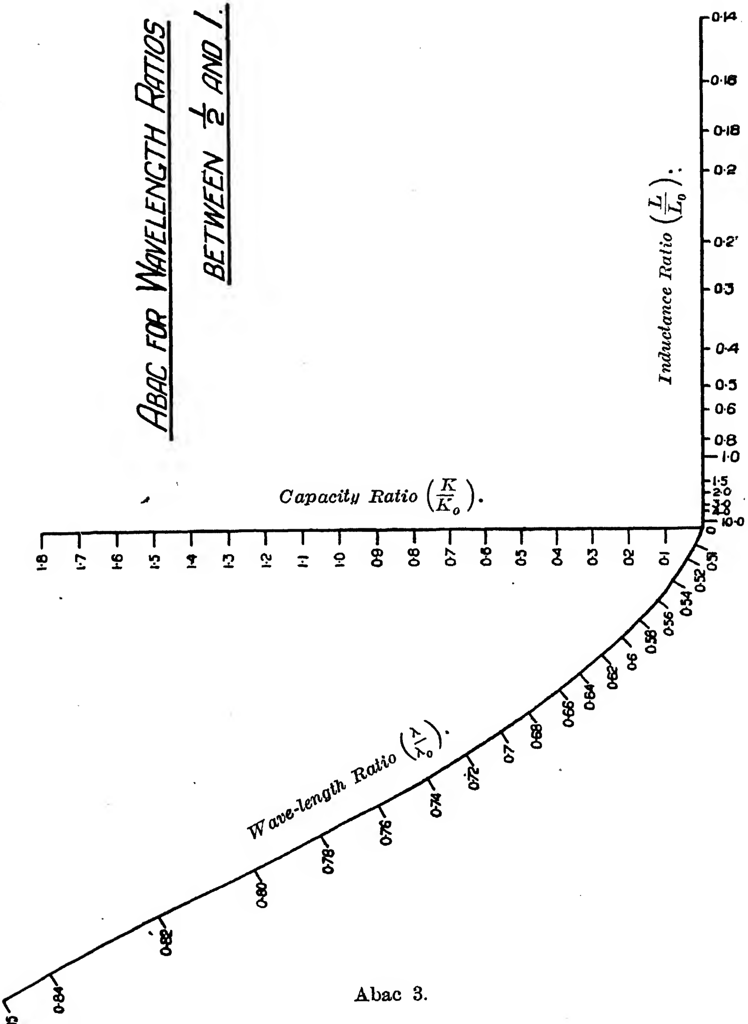
The above enables K_o, L_o, and λ_o to be obtained. It is now required to find the wave-length of the antenna under working conditions, that is, with either series inductance or capacity, or both.

The following three examples are taken directly from Dr. Eccles' article (*loc. cit.*) and illustrate the use of all his abacs.

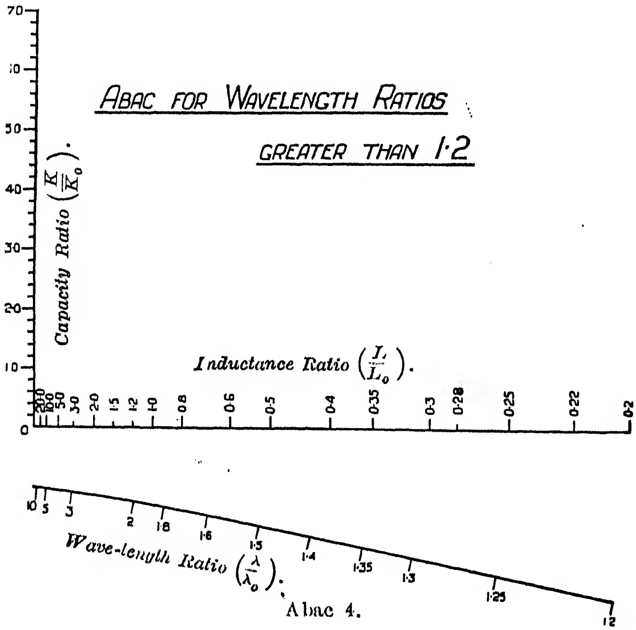
Example :—

$$L_o = 142{,}000 \text{ cms.}$$
$$K_o = 1{,}680 \text{ cms. (E.S. units).}$$
$$\lambda_o = 618 \text{ metres.}$$

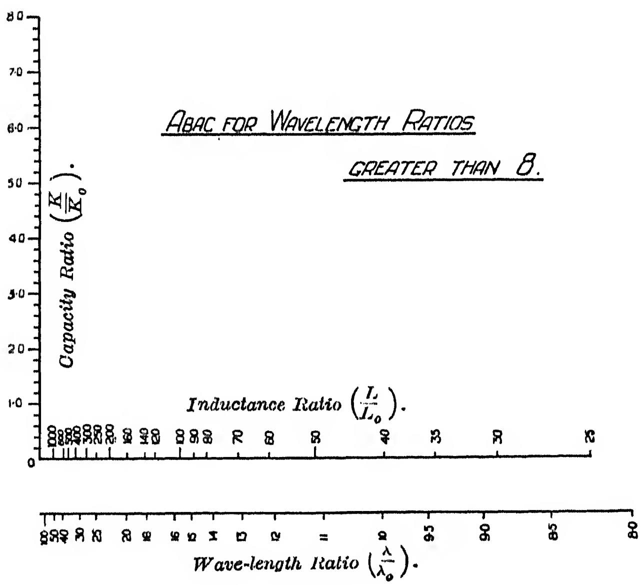
(Note.—In practical forms of antenna the capacity and inductance are distributed, and the effective capacity and inductance


ABAC FOR WAVELENGTH RATIOS
BETWEEN 1/2 AND 1.
Inductance Ratio (L/L_o).
Capacity Ratio (K/K_o).
Wave-length Ratio (λ/λ_o).

Abac 3.


ABAC FOR WAVELENGTH RATIOS
GREATER THAN 1·2
Capacity Ratio $\left(\frac{K}{K_0}\right)$.
Inductance Ratio $\left(\frac{L}{L_0}\right)$.
Wave-length Ratio $\left(\frac{\lambda}{\lambda_0}\right)$.

Abac 4.


ABAC FOR WAVELENGTH RATIOS
GREATER THAN 8.
Capacity Ratio $\left(\frac{K}{K_0}\right)$.
Inductance Ratio $\left(\frac{L}{L_0}\right)$.
Wave-length Ratio $\left(\frac{\lambda}{\lambda_0}\right)$.

Abac 5.

depend on the frequency, so that each individual case must be considered for a specified wave-length or frequency. The most definite method about which there can be no doubt, is the natural wave-length or frequency of the aerial.)

EXAMPLE 19A.—Let no inductance be added.
Let series condenser have a capacity

$$K = 485 \text{ cms.}$$

Then
$$\frac{K}{K_o} = 0{\cdot}286.$$

Abac I gives for this capacity ratio the wave-length ratio $\frac{\lambda}{\lambda_o} = 0{\cdot}623$.

Therefore $\lambda = 0{\cdot}623 \times 618 = 385$ metres.

EXAMPLE 19B.—Let no capacity be added.
Let the added inductance be 682,000 cms.

Then
$$\frac{L}{L_o} = \frac{682{,}000}{142{,}000} = 4{\cdot}8.$$

Abac 2 gives for this inductance ratio the wave-length ratio $\frac{\lambda}{\lambda_o} = 3{\cdot}56$.

Therefore $\lambda = 3{\cdot}56 \times 618 = 2{,}200$ metres.

EXAMPLE 19C.—Let both capacity $K = 1{,}030$ cms. and inductance $L = 27{,}300$ cms. be connected in series with the above aerial.

$$\text{Inductance ratio } \frac{L}{L_o} = 0{\cdot}192.$$

$$\text{Capacity ratio } \frac{K}{K_o} = 0{\cdot}614.$$

Mark these on their respective ratio axes on abac 3, and by stretching a fine thread or by means of a straight-edge, read the intersection with the wave-length ratio scale.

$$\frac{\lambda}{\lambda_o} \text{ in this case is } 0{\cdot}79.$$

Thus
$$\lambda = 0{\cdot}79 \times 618 = 488 \text{ metres.}$$

On Coupling. Generally speaking, the coefficient of coupling is small. For such measurements as have been described the coupling can be made very small.

The added inductance of a coupling coil is $L(1 - k^2)$ where k is the coefficient of coupling.

Even where $k = 10$ per cent., the error in L is only ·1 per cent., which is usually negligible.

Where k is known it can be used to modify the value of L in the manner indicated, though it has generally an insignificant value.

Where L itself is small compared with L_0 then the result of taking $L(1 - k^2)$ or simply L is the same.

Example 20 (Formula par. 7).—A terminal choking coil of a H.T. transformer is wound with 500 turns of wire with a spacing of 10 turns per cm. The coil diameter is 8 cms. and length 50 cms. Find its approximate inductance.

Formula $L = 4\pi^2 a^2 N^2 b$ cms. is accurate enough for coils of this description.

$$a = 4,\ b = 50,\ N = 10.$$

$$L = 4\pi^2 16 \times 100 \times 50 \text{ cms.}$$

$$= 3{\cdot}165 \times 10^6 \text{ cms., or about 3 milli-henries.}$$

Example 21 (Formula par. 5c).—Find the capacity of a moving plate condenser having a composite dielectric of ebonite and air.

Distance apart of plates $d = 0{\cdot}1$ cm.

Thickness of ebonite dielectric $t = 0{\cdot}08$ cm.

Specific inductive capacity $k = 2{\cdot}5$, say.

Moving plates $R = 6$ cms., $r = 2$ cms., 20 in number.

Area $= \pi(R^2 - r^2)n = \pi(6^2 - 2^2)\,20 = 2{,}010$ sq. cms.

Equivalent air thickness

$$= (d - t) \times \frac{t}{k} = (0{\cdot}1 - 0{\cdot}08) + \frac{0{\cdot}08}{2{\cdot}5} = 0{\cdot}052 \text{ cm.}$$

$$K = \frac{2{,}010}{11{\cdot}31 \times 10^6 \times 0{\cdot}052} = 0{\cdot}00342 \text{ mfd.}$$

Example 22 (Formula par. 5d).—Find the capacity of two parallel circular metal plates 30 cms. in diameter ($r = 15$), separated by mica dielectric 0·1 cm. thick.

Take S.I.C. $k = 5$. Thickness of metal $= 0{\cdot}25$ cm.,

i.e. $r = 15$, $d = 0{\cdot}1$, $t = 0{\cdot}25$, $k = 5$.

From 5d. $K = \left[\frac{15^2}{0\cdot 4} + \frac{15}{4\pi}\left(\log_e \frac{16\pi 15(0\cdot 35)}{(0\cdot 1)^2} - 1 + \frac{0\cdot 25}{0\cdot 1}\log_e \frac{0\cdot 35}{0\cdot 25}\right)\right]$

$$\frac{5}{9 \times 10^5} \text{ mfds.}$$

$$= \left[563 + 1\cdot 193\,(2\cdot 303 \log_{10} 26{,}400 - 1 + 2\cdot 5 \times 2\cdot 303\right.$$

$$\left.\log_{10} 1\cdot 4)\right] \frac{5}{9 \times 10^5} \text{ mfds.}$$

$$= \left[563 + 1\cdot 193 \times 10\cdot 022\right] \frac{5}{9 \times 10^5} \text{ mfds.}$$

$$= \left[\;563 \;+\; 11\cdot 96\;\right] \frac{5}{9 \times 10^5} \text{ mfds.}$$

$$= 0\cdot 003188 \text{ mfds.}$$

Neglecting the effect of t and using the simpler formula,

$$K = 563 \times \frac{5}{9 \times 10^5} = 0\cdot 003125 \text{ mfds.}$$

EXAMPLE 23 (Formula, par. 27).—A stay wire is attached to a pole 400 feet above the ground ($b = 400$).

The distance from the anchor point to foot of mast $a = 300$ feet.

The height of the point at which the tangent to the stay at the ground intersects the pole c is 370 feet. Find the tension in the stay for a cable weighing 1·5 lbs. per foot.

$$T = 1\cdot 5\,\frac{(300^2 + 370^2)}{2\,(400 - 370)} \text{ lbs.}$$

$$= 1\cdot 5\,.\,\frac{90{,}000 + 137{,}000}{2 \times 30}\;.\text{ lbs.}$$

$$= 5{,}670 \text{ lbs.}$$

EXAMPLE 24 (Formula, par. 29).—A bobbin of wire is known to have a core diameter of 1 inch ($d = 1$). The outside diameter D is 3 inches. The length of winding between cheeks $l = 6$ inches. Diameter of covered wire $\delta = 100$ mils. (*i.e.*, 0·1 inches, found by counting, if the winding is neatly done, *i.e.*, 10 turns per inch in this case). Find the length of wire on the bobbin.

$$L = 21{,}820 \times \frac{l}{\delta^2}(D^2 - d^2) \text{ yards}$$
$$= 21{,}820 \times \frac{6}{(100)^2}(3^2 - 1^2)$$
$$= \frac{21{,}820 \times 6 \times 8}{10{,}000}$$
$$= 104{\cdot}8 \text{ yards, say } 105 \text{ yards.}$$

Example 25 (Formula, par. 11).—Find the relative increase in resistance of a wire 5 mm. diameter compared with its c.c. or steady current resistance for a frequency of 5×10^5 ($\lambda = 600m$).

This frequency may be called high, and therefore formula :—

$$R_n = R_o\, r\sqrt{0{\cdot}0058n} \text{ can be used.}$$
$$r = 0{\cdot}25;\ n = 5 \times 10^5.$$

Then
$$\frac{R_n}{R_o} = 0{\cdot}25\sqrt{0{\cdot}0058 \times 5 \times 10^5}.$$
$$= 0{\cdot}25\sqrt{2{,}900}$$
$$= 13{\cdot}45.$$

Taking Wire Table 18 for high frequency resistances of copper wires,

R_o for 1 metre of this wire $= 0{\cdot}000886$ ohms,

R_n ,, ,, ,, $= 0{\cdot}0124$ ohms at $n = 5 \times 10^5$,

whence $\frac{R_n}{R_o} = \frac{0{\cdot}0124}{0{\cdot}000886} = 14{\cdot}0$, or by Zenneck's table slightly high compared with Rayleigh's formula.

For $n = 5 \times 10^4$ ($\lambda = 6{,}000m$) in the above

$\frac{R_n}{R_o}$ by formula $= 0{\cdot}25\sqrt{290} = 4{\cdot}26$.

$\frac{R_n}{R_o}$ from table $= \frac{0{\cdot}004}{0{\cdot}000886} = 4{\cdot}51$, slightly higher than by formula.

Notes and Example 26 (Synopsis of formulæ, par. 11, of equations).—High frequency current distribution in conductors :—

Let μ = permeability of material of conductor.
σ = specific resistance of conductor.
p = $2\pi f$. f = cycles per sec.
a = radius of conductor in cms.
x = depth from surface in cms.
I_x = current intensity at depth x.
I_{max} = ,, ,, surface,

Then current at any instant at depth x is

$$I_x = I_{\max}\,\epsilon^{-\left(\frac{2\pi\mu p}{\sigma}\right)^{\frac{1}{2}}x} \cos\left[\left(pt - \left(\frac{2\pi\mu p}{\sigma}\right)^{\frac{1}{2}}x\right)\right].$$

The actual distribution of current is independent of time, and taking the case of copper, where $\mu = 1{\cdot}0$ and $\sigma = 1{,}600$,

$$\frac{I_x}{I_{\max}} = \epsilon^{-0{\cdot}15708x\sqrt{f}} \quad . \quad . \quad . \quad \text{(i.).}$$

Again, for copper

$$I^2_{\text{RMS}} \text{ is approx.} = \frac{I^2_{\max}}{2a(0{\cdot}15708\sqrt{f})}, \text{ where } f \text{ is great,}$$

$$= \frac{I^2_{\max}}{0{\cdot}31416a\sqrt{f}}.$$

So that

$$\frac{I_{\text{RMS}}}{I_{\max}} = \frac{1}{\sqrt{0{\cdot}31416a\sqrt{f}}}$$

or

$$I_{\max} = I_{\text{RMS}}\sqrt{0{\cdot}31416a\sqrt{f}} \quad . \quad . \quad . \quad \text{(ii.)}$$

From (i.)

$$I_x = \frac{I_{\max}}{\epsilon^{0{\cdot}15708x\sqrt{f}}}\;.$$

From (ii.)

$$= \frac{I_{\text{RMS}}\sqrt{0{\cdot}31416a\sqrt{f}}}{\epsilon^{0{\cdot}15708x\sqrt{f}}}.$$

Thus, in order that the current at a depth x cms. may be $\frac{1}{100}$th of the R.M.S. current carried by the conductor, the following relations hold :—

$$\frac{I_x}{I_{\max}} = \frac{1}{100} = \frac{\sqrt{0{\cdot}31416a\sqrt{f}}}{\epsilon^{0{\cdot}15708x\sqrt{f}}}.$$

so that

$$100\sqrt{0{\cdot}31416a\sqrt{f}} = \epsilon^{0{\cdot}15708x\sqrt{f}} \quad . \quad . \quad \text{(iii.)}$$

Thus for any given conductor size (radius a) and frequency f, a depth (x cms.) can be found at which the current intensity is $\frac{1}{100}$th of the R.M.S. value carried by the conductor.

EXAMPLE 26A.—Find the value of x for $f = 5 \times 10^4$ (*i.e.*, $\lambda = 6{,}000$) so that the current may be $\frac{1}{100}$th of the R.M.S. value, the conductor radius "a" being 1·0 cm.

From (iii.) $100\sqrt{0{\cdot}31416} \times 1{\cdot}0\sqrt{5 \times 10^4} = \epsilon^{0{\cdot}15708x\sqrt{5 \times 10^4}}$

$$\epsilon^{35{\cdot}15x} = 839 = \epsilon^X \text{ say,}$$

whence
$$X = 2{\cdot}303 \log_{10}^{-1} 839$$
$$= 2{\cdot}303 \times 2{\cdot}9238$$
$$x = \frac{2{\cdot}303 \times 2{\cdot}938}{35{\cdot}15} = 0{\cdot}1919 \text{ cm.}$$

Hence in the above case a tube 2 cms. diameter with wall 0·2 cm. thick would offer just about as much carrying capacity as the solid rod 2 cms. in diameter.

A more usual case is where it is required to find x such that the current intensity may be $\frac{1}{100}$th (or some other specified fraction) of the "skin" or maximum current intensity. This will now be dealt with.

From (i.)
$$\frac{I_x}{I_{\max}} = \epsilon^{-0{\cdot}15708x\sqrt{f}} = \frac{1}{100}.$$

Thus
$$\epsilon^{0{\cdot}15708x\sqrt{f}} = 100 = \epsilon^X \text{ say,}$$

whence
$$X = 2{\cdot}303 \log_{10}^{-1} 100$$
$$= 4{\cdot}606$$

and
$$0{\cdot}15708x\sqrt{f} = 4{\cdot}606 \quad . \quad . \quad . \quad . \quad . \quad \text{(iv.)}$$

Example 26b.—For a frequency $f = 5 \times 10^4$ ($\lambda = 6{,}000m$) find the value of x where the current intensity is $\frac{1}{100}$th of the maximum or "skin" intensity.

From (iv.)
$$x = \frac{4{\cdot}606}{0{\cdot}15708\sqrt{5 \times 10^4}} = 0{\cdot}1311 \text{ cm.}$$

Example 26c.—For a frequency $f = 5 \times 10^4$ ($\lambda = 6{,}000m$) find the value of the current intensity in terms of the maximum or surface value at a point $x = 0{\cdot}1$ cm. below the surface.

From (i.) the value is
$$\frac{1}{\epsilon^{0{\cdot}15708 \times 0{\cdot}1\sqrt{5 \times 10^4}}}.$$
$$= \frac{1}{\epsilon^{3{\cdot}51}}$$
$$= \frac{1}{14{\cdot}21}$$
$$= 0{\cdot}0704 \text{ of the "skin" or maximum value.}$$

Example 26d.—Find the value of the "skin" current intensity compared with the value of the R.M.S. current, for a wire 0·25 cm. radius where frequency $f = 5 \times 10^5$ ($\lambda = 600m$).

Rearranging (ii.) $$\frac{I_{\max}}{I_{\text{RMS}}} = \sqrt{0{\cdot}31416a\sqrt{f}}$$
$$= \sqrt{0{\cdot}31416 \times 0{\cdot}25 \times \sqrt{5 \times 10^5}}$$
$$= 7{\cdot}47.$$

Table 33 has been worked out from formula (iv.) and gives a few values of x for various frequencies at which the current value is $\frac{1}{100}$th of the maximum or " skin " value.

$$x = \frac{29{\cdot}30}{\sqrt{f}} \text{ cms. (iv.) modified.}$$

NOTES 27.—*Notes on Insulating Materials.* (Data abstracted from " Standard Handbook for Electrical Engineers," McGraw.)

General.—The first requisite of an insulator is that it must resist puncture or breakdown by the maximum e.m.f.'s, to which it may be subjected under working conditions.

The working conditions in wireless telegraphy are often, comparatively speaking, severe, for, owing to the high frequency at which the electric stresses alternate, and the high maxima existing compared with the R.M.S. values obtaining, materials in general will break down under comparatively speaking low e.m.f.'s.

High temperature lowers the dielectric strength of insulating materials ; and high frequency e.m.f.'s produce considerable heating in a dielectric if the stress is at all great.

Moisture will reduce the dielectric strength of materials which are hygroscopic, and tend to reduce the voltage at which " flash over " occurs with non-hygroscopic substances such as glass, porcelain, etc.

The following gives a few of the different classes of dielectrics available :—

Dielectrics suitable for High Temperatures.		Dielectrics suitable for Damp Situations.		Mechanically strong Dielectrics.	
Aetna.	Mica.	Aetna.	Gutta Percha.	Aetna.	Micanite.
Ambroin.	Mineralite.	Ambroin.	Horn Fibre.	Ambroin.	Mineralite.
Electro-Enamel.	Porcelain.	Asphalt.	Megomit.	Celluloid.	Porcelain.
Horn Fibre.	Sterling Varnishes.	Celluloid.	Mica.	Ebonite.	Presspahn.
Lava.		Ebonite.		Horn Fibre.	Psychiloid.
		Electro-Enamel.		Lava.	Vulcanised Fibre
				Leatheroid.	
				Megomit.	

Aetna.—This can be used for strain insulators, having fairly high tensile strength and high breakdown voltage. Tests on a 1 m.m. slab after boiling in water and being cooled to 30° C. gave

Dielectric strength	3,500 V. per m.m.
Tensile strength	1,400 lbs. per sq. inch.
Compressive strength	728 lbs. per sq. inch.

Ambroin.—Can be moulded, and stands high temperature and can be machined. After a water boiling test as above a slab 0·33 m.m. thick gave

Dielectric strength 10,600 V. per m.m.

A slab 5 m.m. gave

Dielectric strength	7,200 V. per m.m.
Tensile strength	2,140 lbs. per sq. inch.
Compressive strength	1,960 lbs. per sq. in.

Specific resistance $\sigma = 0{\cdot}16 \times 10^6$ megohms per cm.^{3}

Asphalt.—Used for running into cable ducts and channels. Resists water well and is easily cut out and renewed.

Celluloid.—Can be worked at 100° C. as an insulating material and can be moulded into any form by soaking in boiling water.

Safe working pressure 14,000 V. per m.m. at 20° C.
" " " 6,000 V. per m.m. at 100° C.

A thin test piece 0·2 m.m. gave a

Dielectric strength 22,500 V. per m.m. at 20° C.
" " 8,000 V. per m.m. at 100° C.

Ebonite.—Vulcanised rubber. Unsuitable for use where it is liable to get oily or where exposed to light and air. It is brittle but strong and fairly easily worked. Quickly blunts turning tools.

Dielectric strength	35,000 V. per m.m.
Tensile strength	1,120 lbs. per sq. inch.
Compressive strength	2,200 lbs. per sq. inch.

Electro-Enamel.—Used as a heat conducting insulating enamel. Said to be an acid and moisture-proof varnish with good cementing properties. Coils wound with the enamel "tacky," cement together and require no further binding together.

Empire Insulating Varnish.—This is flexible, and acid and moisture-proof. Used for impregnating coils which is done at 100° C.

Gutta-Percha.—Suitable for made-up insulating materials such as basis of cable insulation. Rapidly oxidises and must therefore be kept from air and light.

Softens at 46° C. Plastic at 50° C. and melts at 100° C.

Only resin oil is beneficial in raising the dielectric strength and acting as a preservative.

(Untreated) Dielectric strength 10,000 to 25,000 V. per m.m. depending on thickness of specimens, being greater for the thinner specimens.

Tensile strength 3,500 lbs. per sq. inch will stand 1,000 lbs. per sq. inch without further extension when once stretched.

Specific resistance $\sigma = 450 \times 10^6$ megohms per $cm.^3$

Horn Fibre.—This is an expensive but very good insulator. It is mechanically strong and can be turned.

Dielectric strength 12,000 V. per m.m. untreated, and about double this when impregnated with oil.

Lava.—This can be machined like brass when in the natural state ; but after baking at 1,100° C. it becomes very hard.

Dielectric strength 3,000 to 10,000 V. per m.m.

Leatheroid.—This is very tough, running next to horn fibre. When untreated its dielectric strength varies from 5,000 to 14,000 V. per m.m. When varnished, dielectric strength is about 9,000 to 16,000 V. per m.m.

Megomit.—Several grades of this are made under different names. They all contain mica as a base ; flakes of which are stuck together and to some binding material with various adhesives.

	Dielectric Strength.
Hard Megomit (shellaced mica)	34,000 to 50,000 V. per m.m. and stands 6,750 V. per. m.m. indefinitely.
Mica Paper (vegetable adhesive)	30,000 to 40,000 V. per m.m. and stands 6,000 V. per m.m. indefinitely.
Micanite* (hard plates)	40,000 V. per m.m. and stands 6,500 V. per m.m. indefinitely.

* See Micanite.

Mica.—This is a clear flaky material, used in all the micanite and megomit compounds.

It is in itself brittle and cannot be bent or moulded.

Dielectric strength	17,000 to 28,000 V. per m.m. depending on quality.
Specific resistance σ is	from $2 \cdot 3$ to $4 \cdot 0 \times 10^6$ megohms. per cm.^{3}

Micanite.—This is done up in "cloths," and "papers," so called because of the nature of the backing to which the mica flakes are cemented.

Micanite made up with shellac is hard and can only be bent when hot.

Micanite made up with a vegetable adhesive is flexible when cold.

	Rigid Plate.	Flexible Plate.	Cloth.	Paper.
Dielectric strength in V. per m.m.	40,000	30,000	17,000	18 000

Mineralite.—A compound of high dielectric strength, tough, and able to work at high temperatures. Little electrical data available.

Paraffin.—This alone is unsuitable for any engineering purposes, but is useful as an impregnating substance for materials which have not to work in hot places.

Dielectric strength	8,100 V. per m.m.
Specific resistance σ	240×10^6 megohms per cm.^{3} at 2,860 V. per m.m. pressure, and $3 \cdot 9 \times 10^9$ megohms per cm.^{3} at 435 V. per m.m. pressure.

Porcelain.—Good for all ordinary temperatures though it fails as an insulator in electric furnace work. Used for supporting H.T. bus bars and lines, in and about a W.T. station.

Dielectric strength	16,350 V. per m.m.
Tensile strength	1,500 to 2,200 lbs. per sq. inch. Average value 1,800.
Compressive strength	15,000 lbs. per sq. inch.

Presspahn.—A prepared paper, impregnated with oil. Very hygroscopic unless treated with a pore filling material.

When treated must not be creased or there is a risk of spoiling the surface, thereby rendering it open to absorb moisture.

Dielectric strength	6,000 to 15,000 V. per m.m.
Specific resistance σ =	11,000 megohms per cm.^{3}

Psychiloid.—This is made from paper pulp. It can be machined like metal, and is unaffected by all oils.

Dielectric strength 9,000 V. per m.m.

Rubber.—Rubber used in insulation work is generally vulcanised. It deteriorates with oil, air, and exposure to light.

Dielectric strength 18,000 V. per m.m.
Tensile strength 800 lbs. per sq. inch.
Specific resistance $\sigma = 177 = 10^7$ megohms per cm.^{3}

Shellac.—Good as a cement for mica, but not very good for impregnating coils unless they are free from mechanical vibration. Too liable to crack to be used as a solid dielectric of any appreciable dimensions.

Dielectric strength about 10,000 V. per m.m.
Specific resistance σ 9×10^9 megohms per cm.^{3}

Vulcanised Fibres.—Can be machined, and are strong and tough. A serious objection to their general use is that they are hygroscopic, but are not spoilt by moisture and subsequent drying.

Dielectric strength 2,000 to 3,000 V. per m.m.
Specific resistance 53 megohms per cm.^{3}

NOTES 28.—*Notes on the Insulating Properties of Solid Dielectrics* (Abstract from *Bull. Bureau Standards*, Vol. II., No. 3).

There are several properties of dielectrics, between no two of which is there any known relationship, the most important being—

(i.) Volume resistivity.
(ii.) Surface leakage.
(iii.) Dielectric absorption.
(iv.) Dielectric strength.
(v.) Dielectric constant or specific inductive capacity.

For high tension work (iv.) is most important, though a knowledge of the others, especially (ii.), is useful. For condenser work (iv.) and (v.) are equally necessary together with (ii.) for very accurate work.

Volume Resistivity.—This is defined as the resistance to the current flowing through the material between two opposite faces of a centimetre cube. This is sometimes called specific resistance.

Effect of Humidity.—Some insulating materials absorb moisture to a greater extent than others; and also take longer to get rid of it when in a drier atmosphere again.

Marble, slate, red fibre, etc., absorb considerably, whilst celluloid, ebonite and glass do not do so to any great extent. When once materials are damp they may be rising in resistance for weeks on end if kept in a dry atmosphere.

Effect of Voltage.—The higher the voltage used in measuring the insulation resistance of certain porous materials, the lower will be the apparent resistance.

Thus, Italian marble has 2·5 times the volume resistivity at 50 volts measuring pressure that it has when measured at 500 volts. Paraffined woods, hard fibre, Bakerlites, etc., are unaffected by the e.m.f. used in resistance measurement.

Effect of Temperature.—The resistance of an insulator at a temperature $t_o°$ C. (absolute) (Rt_o say) may be expressed in terms of the resistance at zero R_o, for any temperature $t°$ C. by the expression

$$R_t = R_o \, \epsilon^{-\frac{qt}{273(273+t)}}$$

where q is a constant depending on the material, which varies from 4,000 to 25,000.

The following short table, selected from numerous values in the above work, shows the ratio of the volume resistivity at 20° C. and 30° C.

Material.	Ratio $\frac{\sigma\,0°}{\sigma 30°}$.	Material.	Ratio $\frac{\sigma 20°}{\sigma 30°}$.	Material.	Ratio $\frac{\sigma 20°}{\sigma 30°}$.
Sealing Wax .	0·9	White Celluloid .	1·8	Opal Glass . .	2·8
Mica, Indian Ruby slightly stained .	1·0	Bakerlite No. 140	2·4	Plate Glass . .	3·2
Hemit . . .	1·2	German Glass .	2·5	Kavalier Glass .	4·5
Moulded Mica .	1·2	Halowax . .	2·5	Sulphur . .	4·9
Shellac . .	1·5	Red Fibre . .	2·6	Khotinsky cement	11·0
Unglazed Porcelain	1·6	Indian Mica, stained .	2·7	Yellow Beeswax .	16·0

Effect of Dielectric Absorption.—When the dielectric absorption is large the current flows for a considerable time after the application of the e.m.f. and this current is not the pure conduction current, which is a constant one, but is the conduction or permanent current *plus* a temporary or absorption current. Thus, measurements of resistivity cannot be made until this temporary or absorption current has subsided. With hard rubber especially is this absorption current noticeable. Thus, after half an hour it is ten times as large as the conduction current; and even after eighteen hours it is not negligible.

Deterioration of Hard Rubber.—This substance deteriorates in sunlight and when exposed to the atmosphere, lowering the *surface* resistivity.

Hard rubber can be renovated by thorough washing in pure distilled water, afterwards being dried and if necessary wiped with a slightly oily cloth, but this latter is only done to bring up the appearance of the piece and does not act beneficially in insulating the surface.

NOTES 29.—*Notes on breakdown voltage and gap length.*

(i.) *Static Charges.*—For small gaps the size of sphere has little effect. Its importance increases as the gap length increases. Thus for very small spheres the breakdown voltage increases only very slowly for increases of gap length, whilst for very large spheres it remains approximately proportional to the gap length up to much greater distances.

(ii.) *Oscillatory Charges.*—The higher the frequency the higher is the voltage necessary to jump a gap of given length. This is due to the voltage at which breakdown would finally occur being reached and passed before the breakdown can start and spread. This is known as the retardation of the discharge and plays an important *rôle* in wireless telegraphy. It is due to the small number of ions in the intervening gap; and can be diminished or eliminated by illuminating the electrodes with ultra-violet light.

A large number of discharges per second passing over the gap may enormously diminish the e.m.f. required to maintain the discharge, this being due to the continuous supply of ions once the discharge has started enabling subsequent breakdowns to occur at much lower e.m.f.'s.

(iii.) *Effect of Pressure and Nature of Gas.*—Increasing the pressure of the gas in which the discharge passes increases the voltage approximately proportionally up to a pressure of 10 atmospheres or thereabouts. The nature of the gas has not much effect on the breakdown e.m.f. for gases such as air, nitrogen, oxygen, carbon-dioxide, etc. However, for hydrogen it is only about half as great as for those mentioned, and less still for helium and argon.

NOTES 30.—*Current and Potential Distribution on various forms of Oscillators.*

(*a*) *Hertz.*—The effective capacity of an oscillator is increased by

the addition of capacity areas at the end; hence the frequency will be lower and wave-length greater than for a simple wire of the same length, and this will be the greater as the end capacities are greater in proportion to the effective capacity of the straight wire portion.

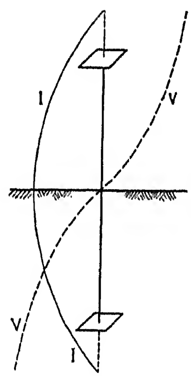


FIG. 1.

The distribution of current and voltage must be of the form indicated by Fig. 1, where I represents current values, and V potential values, using horizontal distances from the vertical for ordinates. The greater the attached end capacities are, the nearer does the current distribution on the vertical part of the wire approach uniformity and the nearer the form factor a is to 1·0 in value.

Since the maximum potential occurs at the end capacities, the current amplitude is much greater compared with this maximum potential amplitude than would be the case for a simple wire of the same length

Comparing such an oscillator for effectiveness, with a simple unloaded linear Hertz oscillator the former has the advantage of its high current value at the anti-node, or earthed, end, and a high value of its form factor a, which in most practical forms of aerial can be taken as sensibly unity.

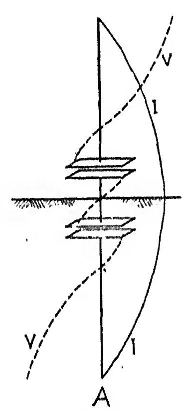


FIG. 2A.

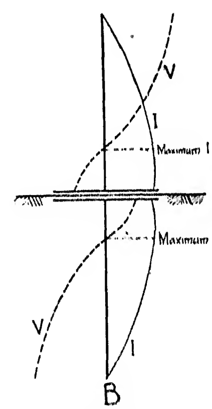


FIG. 2B.

(*b*) *Linear Oscillator containing series Condenser.*—The capacity of the wire and condenser may be considered to be in series, and by bringing the two symmetrical condensers of Fig. 2A together, the plain vertical wire aerial of Fig. 2B is obtained. If the series condenser capacity is very large compared with that of the wire, then the current anti-node and potential node occur at the junction with that large condenser, as they do in the case of the vertical earthed wire of the "plain aerial."

(*c*) *Linear Oscillator containing Series Inductance.*—For a given oscillator, the greater the inductance, the greater the change in frequency and therefore wave-length.

The current amplitude is reduced compared with what it would be for the same potential amplitude with a simple vertical oscillator. The greater the value of the inductance, the greater the wave-length compared with the length of the oscillator, and the nearer does the form factor $\alpha = 0{\cdot}5$.

This all tends to reduce the range of the radiations as against that for a simple oscillator, but since the value of the inductance is greater, the value of the log. dec. of the aerial as a transmitter will be smaller.

$$\left[\text{Note } \delta = \frac{R}{4nL}\right]$$

(*d*) *Linear Oscillator with both series Inductance and Capacity.*—The decrease in wave-length by introducing capacities (*b*) can be partly or wholly compensated for by the addition of series inductances as in (*c*). If the inductance effect predominates, then the wave-length is reduced and the current and potential distribution follows more on the lines of Fig. 3; whilst if the capacity effect predominates, the distribution of current and potential will follow on the lines of Fig. 2B.

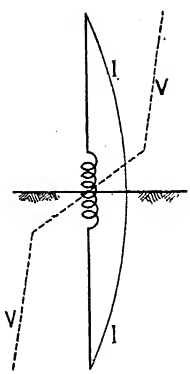


FIG. 3.

If the inductance effect exactly annuls the capacity effect as regards resulting frequency, then the current and voltage distribution is about the same as for a straight oscillator with no coils or capacity in series.

In respect of damping, however, the latter arrangement is very different from the "plain aerial" in that the decrement will be much less when the inductance and capacity are present, and thus they serve a useful purpose without in any way modifying the "plain aerial" wave-length frequency or current and potential distribution.

(*e*) *Grounded Aerials.*—The above discussions have related to straight oscillators of the "open" type; but indication has been made of a position for a plane of symmetry at which the aerial in question might be considered to be erected on the earth's surface, and continue in the same function as before as regards wave-length, current and potential distribution. All modern aerials are grounded,

and the earth connection, if good, can be looked upon as equivalent to an infinite capacity condenser in series with a similar aerial below ground.

NOTES 31.—*Notes on Resonance Curves, and the data to be abstracted from them.*

A resonance curve is obtained by loosely coupling a feebly damped oscillatory circuit containing a suitable current-measuring device and an adjustable capacity condenser to the circuit under examination.

The resonance curve of current is plotted by taking current for ordinates and corresponding frequencies or wave-lengths as abscissæ.

Another method of procedure, especially where comparisons of "sharpness" of tune are required, is to plot ratios of currents obtained for different wave-length settings to currents obtained at resonance as ordinates; against corresponding ratios of frequency of coupled or testing circuit to frequency of resonance as abscissæ.

A resonance curve can also be plotted with voltage as ordinates, in lieu of currents, the peak value again occurring at the same frequency; but since the voltage of a high frequency circuit is more difficult to measure, this method is never employed now where accuracy is desired. It is, however, frequently used for lecture purposes to demonstrate the existence of "peak values" by the use of a Neon or other potential indicating device, and was so used in some of the earlier wireless measuring apparatus.

The abscissa at the peak is called the point of resonance, and the ordinate at the peak is known as the "peak value."

Where I^2_{eff} = current effect.

$I^2_{r\,eff}$ = " " at resonance (peak value of current)

N = discharger frequency per sec. (constant).

n_1 = resonance frequency.

n_2 = frequency of adjustment of test circuit $= n_1$ at resonance.

d_1 = decrement per period of primary.

d_2 = " " " secondary or testing circuit.

E_1 = E.M.F. acting on secondary or testing circuit $= 2\pi n_1 L_1 I_1$.

Then according to Zenneck, "Wireless Telegraphy," p. 104,

$$I^2_{eff} = N \frac{E_1}{64\pi^2 n_1^3 L_2^2} \cdot \frac{d_1 + d_2}{d_1 d_2} \cdot \frac{1}{\left(1 - \frac{n_2}{n_1}\right)^2 + \left(\frac{d_1 + d_2}{2\pi}\right)^2}.$$

$I^2_{r\,eff}$ can be obtained from this by putting $n_1 = n_2$ and simplifying,

$$\text{when} \quad I^2_{r\,eff} = N \frac{E_1}{16 n_1^3 L_2^2} \cdot \frac{1}{d_1 d_2 (d_1 + d_2)}.$$

From a curve plotted with ratios of current effect for ordinates and ratios of frequencies for abscissæ, the following can be inferred :—

The flatter the peak of the curve

(i.) The less sharp will tuning be.

(ii.) The greater will be the sum of primary and secondary decrements $d_1 + d_2$.

(iii.) The closer is the coupling of the two circuits.

Precautions to be taken in order to secure accuracy of measurement for tuning curve.

(1) Air or oil insulated condensers only should be used in the measuring circuit to reduce the losses due to dielectric hysteresis as much as possible.

(2) The inductance coil and connections should be stranded to maintain constant and low resistance $\left(i.e., \text{ constant } d_1 = \frac{R'}{2nL}\right)$ and should be placed so that there is no electrostatic coupling.

*(3) The damping produced by the current-measuring device should be as low as possible, *i.e.*, the most sensitive instrument should be used.

(4) The coupling between the test circuit and the circuit under examination should be as weak as possible.

*(NOTE.—A bolometer or thermo-galvanometer gives better results on this account than, say, a hot wire instrument. When the available energy is too low to operate these instruments successfully then a detector and mirror moving coil galvanometer can be substituted, but this latter requires considerable experimental skill to give good results.)

Use of resonance curves for determining $d_1 + d_1$ of the two circuits (decrement taken per whole period).

(1) Where the measuring circuit condenser is calibrated for capacity K, then currents and K are plotted as ordinates and abscissæ respectively,

and $$d_1 + d_2 = \pi\left(\frac{K_r - K}{K}\right)\sqrt{\frac{1}{\left(\frac{I_{r\,eff}}{I_{eff}}\right)^2 - 1}}.$$

(2) Where the measuring circuit is calibrated for frequencies N, then current and frequency are plotted as ordinates and abscissæ respectively,

and $$d_1 + d_2 = 2\pi\left(\frac{N_r - N}{N}\right)\sqrt{\frac{1}{\left(\frac{I_{r\,eff}}{I_{eff}}\right)^2 - 1}}.$$

(3) Similarly, if the receiving or testing circuit is calibrated in wave-lengths λ (say, for instance, in the case where a wave meter containing a current-measuring device has been used),

then $$d_1 + d_2 = 2\pi\left(\frac{\lambda_r - \lambda}{\lambda}\right)\sqrt{\frac{1}{\left(\frac{I_{r\,eff}}{I_{eff}}\right)^2 - 1}}.$$

(4) An approximation is to find K_1 and K_2 on each side of K_r such that the current is reduced to half the maximum or resonance value when

$$d_1 + d_2 = \frac{\pi}{2}\left(\frac{K_1 - K_2}{K_r}\right).$$

In all the above cases $d_2 = \dfrac{R'}{2nL}$ should be accurately known.

The tuning curve is frequently somewhat unsymmetrical, which indicates condenser leakage, and spoils the results for any accurate analysis of d_2 therefrom. Another and more frequent condition is that the curve, although symmetrical, gives successively increasing values of $d_1 + d_2$ as the points chosen for data for the decrement equation are taken nearer the peak of the curve.

This is very noticeable in circuits containing short spark gaps and is due to the fact that the discharge current values are not exponential in character, and the decrement is therefore not constant over the whole wave train.

(NOTE.—Leakage, both magnetic and electrostatic, into the testing circuits tend to spoil the results and must be most carefully guarded

against. With high voltages it is often very difficult to eliminate considerable (and variable) electrostatic coupling.)

The decrement d_2 of the testing circuit, which should always be small, is nearly always calculable from $\frac{R'}{2nL}$ because R should be so far stranded as to have constant resistance, independent of frequency, whilst L can be either accurately measured or calculated $\left(n = \frac{3 \times 10^8}{\lambda \text{ metres}}\right)$.

Resonance Curves of Coupled Circuits.—When the analysing or test circuit is weakly coupled to two strongly coupled oscillatory circuits, then a tuning curve with twin peaks is obtained.

Table 20 gives values of the coupling coefficient between the two circuits under test, for various values of the ratio of wave-length or frequency at which the twin peaks occur.

Let N' and N'' be the frequencies at the two peaks.

λ' and λ'' „ wave-lengths „ „

N and λ be the values of the frequency and wave-length of each circuit before coupling (they are equal).

$$\text{Then} \quad K' = \left(\frac{N}{N''}\right)^2 - 1 = 1 - \left(\frac{N}{N'}\right)^2$$

$$\text{or} \quad \left(\frac{\lambda''}{\lambda}\right)^2 - 1 = 1 - \left(\frac{\lambda'}{\lambda}\right)^2.$$

If the coupling is very close $K' = \frac{\lambda'' - \lambda'}{\lambda}$.

Resonance Curves of Coupled Circuits. Not closely Coupled.—When two circuits are not very closely coupled then their peak values, although well defined, do not occur at the exact values of N' and N'' as they should.

To separate out the true effect for high accuracy the testing circuit III., in addition to its usual coupling coil, has two widely separated loops M_1 and M_2 so arranged as to be in magnetic coupling with two other loops K_1 and K_2, of the primary and secondary circuits respectively.

M_1 couples with K_1 only.
M_2 „ „ K_2 „
E_1' and E_2' are in phase.
also E_1'' and E_2'' are in phase, but 180° out of place with E_1' and E_2'.

The currents I_1', I_2' depend on the distances M_1K_1 and K_2M_2, and these are adjusted until $E_1'' = E_2''$, then they will neutralise each other.

The result is that an oscillation in II. (frequency N'') has absolutely no effect on the measuring circuit III. which acts as if only the oscillation of frequency N_1' and decrement d_1' existed. Hence a resonance curve plotted in this way gives N' or λ' and d' in the usual way.

To obtain the opposite effect, that is, to eliminate oscillation I. and measure only II., all that is necessary is to revolve loop M_1 (or else loop M_2) through 180° and then proceed as above. E_1' and E_2' now neutralise, whilst E_1'' and E_2'' are added together.

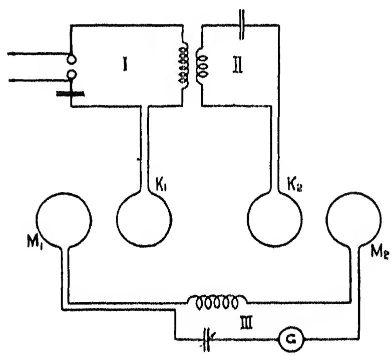


FIG. 4.

General Procedure.—First, a resonance curve is plotted having in general the two maxima already mentioned. To do this M_1 and M_2 are out of action.

Then the distance between M_1 and K_1 or M_2 and K_2 is varied until there is only one maximum,[1] all indications of the second peak having disappeared.

The curve is then the resonance curve of the one oscillation only.

Then M_1 is turned through 180°, and if any trace of the former maximum peak remains it should be eliminated by a final adjustment of the distance between M_1 and K_1 or M_2 and K_2.

The resulting resonance curve is then that of the second oscillation only.

Precautions.—(1) Moving M_1 or M_2 must not change the self-induction of the measuring circuit. The leads to the loops must therefore be run close together to avoid any stray flux linking with the loops of the connections.

(2) The more the peak of one oscillation frequency is eliminated, the more accurately will the position of the other be determined.

[1] See Precaution 3.

(3) Complete elimination of one oscillation frequency can be effected as follows :—

(*a*) Find the value of say N'' approximately.

(*b*) Adjust III. the testing circuit to have this frequency, the direction of the loops M_1, M_2 being such that the e.m.f.'s induced are added. In this way any current of frequency II. will be an absolute maximum. Only then is M_1 turned through 180° and positioned so that the current effect is zero.

This results in a much more complete elimination of frequency II. than before.

The importance of this last precaution is considerable where precise measurements are to be taken because a small residual effect of frequency II. (not necessarily enough to show signs of a maximum in the curve of I.) can nevertheless influence the shape of the upper part of the curve. The readings of the measuring instruments, depending as they do on the mean square of the current, are, relatively speaking, insensitive at low current values.

Conclusion.—The accuracy with which λ' and λ'' can be obtained by this method (and hence N' and N'' as well as K the coefficient of coupling) is very great, though the separate determination of d_1 and d_2 is not so accurate on account of the assumption made, that the current phase relation in the two circuits is exactly 180°.

SECTION IV

Notes on Elementary Arithmetic for Operators.

Contracted Multiplication.—Of the various methods the following is most common. The degree of accuracy to which the answer is required must be decided first. The multiplicand is set down and the number of decimal places required are counted off. The UNITS digit of the multiplier is placed under the last decimal counted, *i.e.*, if the answer is required to three places of decimals the units digit of the multiplier would be set under the third decimal place of the multiplicand. The remainder of the multiplier is set down either side of the units digit in the *reverse order*, no notice being taken of the decimal point. If necessary cyphers may be added to the multiplicand to complete the setting.

The multiplying is commenced with the first figure in the usual way, and the others starting with the figure immediately above

them. A trial must be made on the preceding numbers to find the amount to carry forward, ignoring values up to five, but counting values over five as ten. The decimal point is found by counting along the number of points first decided upon. In the example there are sixty numerals in the ordinary method, while the contracted method only requires forty-six.

Example: Multiply 321·8544 by 22·643 to three places.

321·8544	321·8544
22·643	34622
9655632	6437088
12874176	643709
19311264	193113
6437088	12874
6437088	965
7,287·7491792	7,287·749

Contracted Division.—The principle is much the same as used in contracted multiplication. The number of figures required in the answer is the first thing to be decided. The dividend and divisor are then brought to whole numbers by removing the decimal point and adding cyphers if necessary.

Both the dividend and divisor are written down with one more figure in each than is required in the answer, *i.e.*, 3,218,544 ÷ 22,643 to four figures would be written 32,185 (22,643, each with five figures.

Proceed as in long division for the first case; but for the following figures, instead of adding a cypher to the dividend, strike a figure off the divisor, making a trial to find the amount to carry forward.

To determine the position of the decimal point place the divisor under the dividend with the left hand digits under each other. If the divisor is greater than the dividend for the same number of figures, move the divisor along one place. Now draw a line between the tens and units of the divisor and note the position of the decimal point of the dividend in relation to this line.

If it is to the left the number of places indicates the number of integral figures in the answer.

If it is to the right the number of places indicates the number of cyphers following the decimal point.

If it is on the line the answer is a decimal with no cyphers following the decimal point.

In the examples the subtrahends are omitted in each case; the long division requires 42 figures, while the contracted method only needs 27. Had the subtrahends been shown in the long division 73 figures would have been required.

Example: Divide 321·8544 by 22·643 to five significant figures.

321·8544(22·643	
95424 14·214	32185(2′2′6′4′3
48524	9542 14214
32380	485
97370	32
67980	10
	3|21·8544 two integral
	2|2·643 figures.
	14·214.

When it is desired to find the value of a number raised to a negative index, such as $1{,}066^{-4}$, it is necessary to convert it to another form:—

$$1{,}066^{-4} = \frac{1}{\sqrt[4]{1{,}066}}.$$

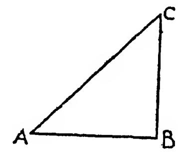
The fourth root of 1,066 may be found as already described, and this value divided into 1 will give the desired result.

$$x^{\circ} = 1 \qquad x^{-2} = \frac{1}{x^2}$$

$$x^2 = x \times x \qquad x^{\frac{2}{3}} = \sqrt[3]{x^2}$$

$$x^3 = x \times x \times x \qquad x^{-\frac{2}{3}} = \frac{1}{x^{\frac{2}{3}}} = \frac{1}{\sqrt[3]{x^2}} = \sqrt[3]{\frac{1}{x^2}}.$$

Trigonometric Functions for Right Angle Triangles.



$$\text{SINE} = \frac{\text{side opposite}}{\text{hypotenuse}}. \quad \text{Sin } A = \frac{BC}{AC}. \quad \text{Sin } C = \frac{AB}{AC}.$$

Side opposite = hypotenuse × sine.

$$AB = AC \times \sin C. \qquad BC = AC \times \sin \text{A}.$$

$$\text{Hypotenuse} = \frac{\text{side opposite}}{\text{sine}}$$

$$AC = \frac{AB}{\sin C} = \frac{BC}{\sin A}$$

$$\text{COSINE} = \frac{\text{side adjacent}}{\text{hypotenuse}}. \quad \text{Cos } A = \frac{AB}{AC} \quad \text{Cos } C = \frac{BC}{AC}$$

Side adjacent = hypotenuse × cosine.

$$AB = AC \times \cos A. \qquad BC = AC \times \cos C.$$

$$\text{Hypotenuse} = \frac{\text{side adjacent}}{\text{cosine}}.$$

$$AC = \frac{AB}{\cos A} = \frac{BC}{\cos C}$$

$$\text{TANGENT} = \frac{\text{side opposite}}{\text{side adjacent}}. \quad \text{Tan } A = \frac{BC}{AB} \quad \text{Tan C} = \frac{AB}{BC}$$

Side opposite = side adjacent × tangent.

$$AB = BC \times \tan C. \qquad BC = AB \times \tan A.$$

$$\text{COTANGENT} = \frac{\text{side adjacent}}{\text{side opposite}}. \quad \text{Cot } A = \frac{AB}{BC} \quad \text{Cot } C = \frac{BC}{AB}$$

Side adjacent = side opposite × cotangent.

$$AB = BC \times \cot A. \qquad BC = AB \times \cot \text{C}.$$

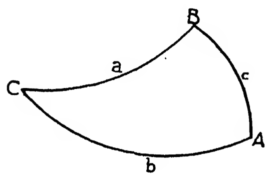
$$\text{SECANT} = \frac{\text{hypotenuse}}{\text{side adjacent}}. \quad \text{Sec } A = \frac{AC}{AB} \quad \text{Sec } C = \frac{AC}{BC}.$$

$$\text{COSECANT} = \frac{\text{hypotenuse}}{\text{side opposite}}. \quad \text{Cosec } A = \frac{AC}{BC} \quad \text{Cosec } C = \frac{AC}{AB}$$

In a right triangle the sum of the squares of the two sides equals the square of the hypotenuse.

$$AC^2 = AB^2 + BC^2$$
$$AB^2 = AC^2 - BC^2$$
$$BC^2 = AC^2 - AB^2$$

Formulæ for Right Angled Spherical Triangles.



$$\text{Sin } a = \frac{\sin b}{\tan B} \qquad \text{Cos } a = \cos b \cos c$$

$$\text{Sin } b = \sin a \sin B \qquad \text{Cos } b = \frac{\cos B}{\sin C}$$

$$\text{Sin } c = \frac{\tan b}{\tan B} \qquad \text{Cos } c = \frac{\cos a}{\cos b}$$

$$\text{Sin } C = \frac{\cos B}{\cos b} \qquad \text{Sin } B = \frac{\sin b}{\sin a}$$

$$\text{Tan } C = \frac{\tan c}{\sin b} \qquad \text{Tan } B = \frac{\tan b}{\sin c}$$

The area of a spherical triangle in square degrees

$$= \cot \tfrac{1}{2}Q = \frac{\cot \frac{1}{2}c \times \cot \frac{1}{2}a \times \cos B}{\sin B}$$

or

$$\sin \tfrac{1}{2}Q = \frac{\sin \frac{1}{2}c \times \sin \frac{1}{2}a \times \sin B}{\cos \frac{1}{2}b},$$

where Q = area.

If R = radius of sphere, the value of one square degree

$$= \frac{R^2}{3{,}285{\cdot}58}$$

Various functions of π.

$$\pi = 3{\cdot}141593 + \text{approximately } 3\tfrac{1}{7}. \qquad \frac{1}{\pi} = 0{\cdot}318310.$$

$2\pi = 6{\cdot}283186$	$\frac{1}{2}\pi = 0{\cdot}5707965$
$3\pi = 9{\cdot}424779$	$\frac{1}{3}\pi = 1{\cdot}047198$
$4\pi = 12{\cdot}566372$	$\frac{1}{4}\pi = 0{\cdot}785398$
$5\pi = 15{\cdot}707965$	$\frac{1}{5}\pi = 0{\cdot}628319$
$6\pi = 18{\cdot}849558$	$\frac{1}{6}\pi = 0{\cdot}523599$
$7\pi = 21{\cdot}991151$	$\frac{1}{7}\pi = 0{\cdot}448799$
$8\pi = 25{\cdot}132744$	$\frac{1}{8}\pi = 0{\cdot}392699$
$9\pi = 28{\cdot}274337$	$\frac{1}{9}\pi = 0{\cdot}349066$

$$\pi^2 = 9{\cdot}86960 \qquad \sqrt{\pi} = 1{\cdot}77245 \qquad \frac{1}{\pi^2} = 0{\cdot}101321 \qquad \frac{1}{\sqrt{\pi}} = 0{\cdot}56419$$

$$\pi^3 = 31{\cdot}0063 \qquad \sqrt[3]{\pi} = 1{\cdot}46459 \qquad \frac{1}{\pi^3} = 0{\cdot}0322515 \qquad \frac{1}{\sqrt[3]{\pi}} = 0{\cdot}682784$$

$$\left(\frac{\pi}{2}\right)^2 = 2{\cdot}46740 \qquad \frac{1}{\frac{\sqrt{\pi}}{2}} = 1{\cdot}25331 \qquad \sqrt{\frac{4}{\pi}} = 1{\cdot}128379 \qquad \sqrt[3]{\frac{6}{\pi}} = 1{\cdot}240701$$

$$\log \pi = 0{\cdot}4971$$
$$,, \quad \pi^2 = 1{\cdot}9943$$
$$,, \quad \sqrt{\pi} = 0{\cdot}2486$$
$$,, \quad \frac{\pi}{2} = 0{\cdot}1961$$

Logarithms.—Briggs or common logs have a base of 10. Hyperbolic, Napierian, or natural logs have a base of 2·71828 +. To get hyperbolic logs multiply the common log by 2·3026. The mantissa will be found in the tables; the characteristic may be found by the following rules:—

The mantissa is always positive, while the characteristic may be positive or negative.

Count the number of figures before the decimal point, and the characteristic will be this number minus 1.

When there is only one figure before the decimal point then there will be no characteristic.

When there is no figure before the decimal point and the first figure is not a cypher, then the characteristic will be minus 1. When the decimal starts with cyphers, the characteristic will be the number of cyphers plus 1, and of minus value.

The mantissa of log 1066 = ·02776.

$\log 1066 = 3{\cdot}02776$	$\log 1{\cdot}066 = 0{\cdot}02776$
$\log 106{\cdot}6 = 2{\cdot}02776$	$\log {\cdot}1066 = \bar{1}{\cdot}02776$
$\log 10{\cdot}66 = 1{\cdot}02776$	$\log {\cdot}01066 = \bar{2}{\cdot}02776$

By reversing this operation the position of the decimal point is found.

To multiply two or more numbers, take out their logs and add together, algebraically; the sum will be the log of the number required.

To divide two or more numbers, take out their logs and subtract in rotation, algebraically; the result will be the log of the number required.

To raise a number to any power, take out the log of the number and multiply by the power; the result will be the log of the number raised to the desired power.

To extract the root of any number, take out the log and divide by the index; the result will be the log of the root.

SPECIFIC GRAVITIES AND APPROXIMATE WEIGHTS.

In the following tables the specific gravities are calculated taking as unity in the case of solids and liquids water at 4° C and atmospheric pressure, and in the case of gases air at 0° C. and atmospheric pressure. The weights are given in avoirdupois pounds per cubic foot. These weights may be calculated by multiplying the specific gravity of any solid or liquid by 62·425, and by multiplying the specific gravity of any gas by ·08073.

In the cases of elements and the more common compounds the chemical symbol is given.

TABLE 34.—METALS.

Substance.	Chemical Symbol.	Sp. Gr.	Weight lbs. per cub. ft.	Substance.	Chemical Symbol.	Sp. Gr.	Weight lbs. per cub. ft.
Aluminium	Al	2·55–2·8	165	Magnesium	Mg	1·75	109
Antimony	Sb	6·712	418	Manganese	Mn	8·0	475
Babbitt Metal	..	7·474	454	Mercury	Hg	13·6	849
Bismuth	Bi	9·90	617	Molybdenum	Mo	8·60	536
Brass	..	8·4–8·7	534	Nickel	Ni	8·3–8·9	537
Bronze, Average	..	8·44	509	Palladium	Pd	11·40	710
Bronze, Phosphor	..	8·88	554	Platinum	Pt	21·522	1330
Cadmium	Cd	8·65	539	Potassium, 50°	K	0·87	54
Calcium	Ca	1·58	98	Rhodium	Rh	10·65	663
Chromium	Cr	5·0	311	Silver	Ag	10·505	655
Copper, Rolled	Cu	8·8–9·0	556	Sodium	Na	·97	60
German Silver	..	8·58	536	Steel, Average	..	7·852	490
Gold	Au	19·25	1205	Strontium	Sr	2·54	158
Gun-metal	..	8·636	537	Tin	Sn	7·409	462
Iridium	Ir	21·78–22·4	1383	Tungsten	W	19·22	1200
Iron, Cast	Fe	7·2	450	Uranium	U	18·33	1140
Iron, Wrought	..	7·6–7·9	485	Zinc, Sheet	Zn	7·20	449
Lead	Pb	11·34	710	Zinc, Cast	Zn	6·86	428

TABLE 35.—VARIOUS SOLIDS.

Substance.	Sp. Gr. Average.	Weight lbs. per cub. ft.	Substance.	Sp. Gr. Average.	Weight lbs. per cub. ft.
Asbestos	2·15	153	Charcoal	0·2	12
Asphalt	1·3	81	Clay, Dry	1·0	63
Borax	1·75	109	Clay, Plastic	1·76	110
Brick, Common	1·9	120	Coal, Anthracite	1·6	97
Brick, Pressed	2·25	140	Coal, Bituminous	1·35	84
Cement, Set	2·9	183	Coke	0·5	30
Cement, Loose	1·44	90	Concrete, Average	2·2	144
Chalk	2·2	137	Cotton	1·48	93

TABLE 35.—VARIOUS SOLIDS—*continued.*

Substance.	Sp. Gr. Average.	Weight lbs. per cub. ft.	Substance.	Sp. Gr. Average.	Weight lbs. per cub. ft.
Earth, Dry Loose	1·2	76	Pumice Stone	0·92	57
Earth, Dry-packed	1·5	95	Quartz	2·5	165
Earth, Mud-packed	1·8	115	Red Lead	8·94	557
Fat	0·95	58	Resin	1·09	68
Fibre	1·39	87	Rubber, Pure	0·94	59
Flint	2·59	161	Rubber, Manufactured	1·5	94
Flour, Loose	0·45	28	Salt, Common	2·13	133
Glass, Common	2·6	162	Saltpetre	2·09	130
Glass, Plate	2·6	162	Shale	2·6	172
Glass, Crystal	2·95	184	Slate	2·8	176
Glass, Flint	3·8	247	Starch	1·53	96
Granite, Scotch	2·65	165	Stone, Bath	1·96	122
Graphite	2·1	131	Stone, Common	2·52	157
Ivory	1·87	114	Stone, Portland	2·37	148
Leather	0·95	59	Stone, Sandstone	2·2	137
Lime, Quick-	0·8	50	Sugar	1·6	100
Marble, Average	2·7	165	Sulphur	2·03	126
Mica	2·8	174	Talc	2·5	156
Pitch	1·07	69	Tallow	0·94	59
Plaster of Paris	1·18	73	Vulcanite	1·52	95
Porcelain	2·25	143	Wax, Paraffin	0·97	60

TABLE 36.—WOODS, DRY.

Substance.	Sp. Gr. Average.	Weight lbs. per cub. ft.	Substance.	Sp. Gr. Average.	Weight lbs. per cub. ft.
Alder	0·52	33	Holly	0·85	53
Almond	0·86	54	Hornbeam	0·72	45
Ash, American	0·74	46	Ironwood	1·20	75
Ash, European	0·7	43	Jarrah	0·92	57
Ash, Mountain	0·7	43	Juniper	0·61	37
Bamboo	0·4	25	Lancewood	0·92	57
Beech, Common	0·75	46	Larch	0·62	38
Beech, Australian	0·53	33	Lignum Vitæ	1·00	62
Birch, American	0·68	42	Lime or Linden	0·54	32
Birch, English	0·62	38	Logwood	0·92	57
Boxwood, Cape	0·93	58	Mahogany, East Indian	0·69	43
Boxwood, Common	1·3	76	Mahogany, Cuban	0·78	47
Boxwood, West Indian	0·79	49	Mahogany, Australian	1·11	69
Cedar, Cuban	0·45	28	Mahogany, Spanish	0·86	53
Cedar, Virginian	0·5	33	Maple, Bird's-eye	0·58	36
Cedar, Indian	1·32	82	Maple, Hard	0·68	42
Cherry, American	0·59	36	Maple, Soft	0·62	38
Cherry, English	0·62	38	Oak, African	0·96	59
Chestnut, Sweet	0·66	40	Oak, American	0·86	54
Chestnut, Horse	0·57	35	Oak, Danzig	0·83	52
Cocus	1·55	96	Oak, English	0·73	46
Cogwood	1·08	67	Pine, Pitch	0·71	44
Cork	0·25	16	Pine, Red	0·55	34
Cottonwood, American	0·55	34	Pine, White	0·43	27
Cypress	0·65	40	Pine, Yellow	0·46	28
Dogwood	0·79	49	Plane	0·57	35
Ebony	1·19	73	Poplar	0·43	26
Elder	0·65	40	Rosewood	0·88	55
Elm, American	0·71	44	Satinwood	0·94	58
Elm, Common	0·68	42	Spruce	0·48	30
Fir, Danzig	0·62	38	Sycamore	0·65	40
Fir, Riga	0·58	36	Teak	0·62	38
Fir, Silver	0·48	30	Walnut	0·67	41
Fir, Spruce	0·48	30	Whitewood	0·53	33
Hackmatack	0·63	39	Willow	0·53	33
Hazel	0·64	39	Yew	0·84	52
Hickory	0·78	47			

TABLE 37.—LIQUIDS.

Substance.	Chemical Symbol.	Sp. Gr.	Weight lbs. per cub. ft.	Substance.	Chemical Symbol.	Sp. Gr.	Weight lbs. per cub. ft.
Acid, Acetic .	—	1·10	66	Oil, Mineral .		0·90–0·93	57
Acid, Hydrochloric .	HCl	1·20	75	Paraffin .		0·87–0·91	56
Acid, Nitric .	HNO_3	1·50	94	Petroleum .		0·87	54
Acid, Sulphuric	H_2SO_4	1·84	112	Tar . .		1·20	75
Alcohol, Pure .		0·796	50	Turpentine .		0·86–0·87	52
Chloroform .		1·526	95	Water, Fresh, 4° C. .	H_2O	1·0	62·4
Ether . .		0·736	46	Water, Sea .		1·02–1·03	64
Oil, Vegetable.		0·91–0·94	58				

TABLE 38.—GASES.

Substance.	Chemical Symbol.	Sp. Gr.	Weight lbs. per cub. ft.	Substance.	Chemical Symbol.	Sp. Gr.	Weight lbs. per cub. ft.
Acetylene .	C_2H_2	0·90	·068	Hydrogen .	H	0·069	·005
Air . .	...	1·0	·081	Nitrogen .	N	0·97	·078
Ammonia Gas.	NH_3	0·589	·053	Oxygen .	O	1·106	·089
Carbon Dioxide	CO_2	1·52	·123	Steam, 212° F. . .	H_2O	0·488	·05
Carbon Monoxide . .	CO	0·967	·073	Water Vapour	H_2O	0·622	·055

TABLE 39.—FRACTIONAL, DECIMAL AND METRIC EQUIVALENTS OF ONE INCH.

Inches. Fraction.	Inches. Decimal.	Millimetres.	Millimetres.
$\frac{1}{64}$	·015625	·3968	
$\frac{1}{32}$	·03125	·794	
—	·039	—	1
$\frac{3}{64}$	·046875	1·191	
$\frac{1}{16}$	·0625	1·587	
$\frac{5}{64}$	·078125	1·984	
—	·079	—	2
$\frac{3}{32}$	·09375	2·381	
$\frac{7}{64}$	·109375	2·778	
—	·118	—	3
$\frac{1}{8}$	·125	3·175	
$\frac{9}{64}$	·140625	3·572	
$\frac{5}{32}$	·15625	3·969	
—	·157	—	4
$\frac{11}{64}$	·171875	4·365	
$\frac{3}{16}$	·1875	4·762	
—	·197	—	5
$\frac{13}{64}$	·203125	5·159	
$\frac{7}{32}$	·21875	5·556	
$\frac{15}{64}$	·234375	5·953	
—	·236	—	6
$\frac{1}{4}$	·25	6·35	
$\frac{17}{64}$	·265625	6·745	
—	·276	—	7
$\frac{9}{32}$	·28125	7·144	
$\frac{19}{64}$	·296875	7·540	
$\frac{5}{16}$	·3125	7·137	
—	·315	—	8
$\frac{21}{64}$	·328125	8·334	
$\frac{11}{32}$	·34375	8·731	
—	·354	—	9
$\frac{23}{64}$	·359375	9·128	
$\frac{3}{8}$	·375	9·525	

Inches. Fraction.	Inches. Decimal.	Millimetres.	Millimetres.
$\frac{25}{64}$	·390625	9·921	
—	·394	—	10
$\frac{13}{32}$	·40625	10·319	
$\frac{27}{64}$	·421875	10·716	
—	·433	—	11
$\frac{7}{16}$	·4375	11·112	
$\frac{29}{64}$	·453125	11·509	
$\frac{15}{32}$	·46875	11·906	
—	·472	—	12
$\frac{31}{64}$	·484375	12·303	
$\frac{1}{2}$	·5	12·70	
—	·512	—	13
$\frac{33}{64}$	·515625	13·096	
$\frac{17}{32}$	·53125	13·493	
$\frac{35}{64}$	·546875	13·890	
—	·551	—	14
$\frac{9}{16}$	·5625	14·287	
$\frac{37}{64}$	·578125	14·684	
—	·591	—	15
$\frac{19}{32}$	·59375	15·081	
$\frac{39}{64}$	·609375	15·478	
$\frac{5}{8}$	·625	15·875	
—	·630	—	16
$\frac{41}{64}$	·640625	16·271	
$\frac{21}{32}$	·65625	16·668	
—	·669	—	17
$\frac{43}{64}$	·671875	17·065	
$\frac{11}{16}$	·6875	17·462	
$\frac{45}{64}$	·703125	17·859	
—	·709	—	18
$\frac{23}{32}$	·71875	18·256	
$\frac{47}{64}$	·734375	18·652	

Inches. Fraction.	Inches. Decimal.	Millimetres.	Millimetres.
—	·748	—	19
$\frac{3}{4}$	·75	19·050	
$\frac{49}{64}$	·765625	19·446	
$\frac{25}{32}$	·78125	19·843	
—	·787	—	20
$\frac{51}{64}$	·796875	20·240	
$\frac{13}{16}$	·8125	20·637	
—	·827	—	21
$\frac{53}{64}$	·828125	21·034	
$\frac{27}{32}$	·84375	21·431	
$\frac{55}{64}$	·859375	21·827	
—	·866	—	22
$\frac{7}{8}$	·875	22·225	
$\frac{57}{64}$	·890625	22·621	
—	·906	—	23
$\frac{29}{32}$	·90625	23·018	
$\frac{59}{64}$	·921875	23·415	
$\frac{15}{16}$	·9375	23·812	
—	·945	—	24
$\frac{61}{64}$	·953125	24·209	
$\frac{31}{32}$	·96875	24·606	
$\frac{63}{64}$	·984	25	25
1	—	25·4	

Inches.	Millimetres.
1	25·4
2	50·799
3	76·199
4	101·598
5	126·993
6	152·397
7	177·797
8	203·196
9	228·596
10	253·995
11	279·395
12	304·794

TABLE 40.—ENGLISH AND METRIC CONVERSION TABLE.

	Feet to metres.	Metres to feet.	Square inches to square centi-metres.	Square centi-metres to square inches.	Square feet to square metres	Square metres to square feet.	Cubed inches to cubed centi-metres.	Cubic centi-metres to cubed inches.	Cubic feet to cubed metres.	Cubic metres to cubed feet.	Pounds to kilos.	Kilos. to pounds.	Pounds per sq. in. to kilos. per sq. cm.	Kilos. per sq. cm. to lbs. per sq. in.	Pounds per foot to kilos. per metre.	Kilos. per metre to lbs. per sq. in.	
1	·3048	3·2809	6·4514	·15501	·0929	10·764	16·386	·061027	·028315	35·317	·45359	2·2046	·07031	14·223	1·4882	·672	1
2	·60959	6·5618	12·9027	·31001	·1858	21·529	32·772	·122054	·056631	70·633	·90719	4·4092	·140619	28·446	2·9764	1·3439	2
3	·91438	9·8427	19·3541	·46502	·2787	32·293	49·158	·183081	·084946	105·95	1·36078	6·6139	·210929	42·668	4·4646	2·0189	3
4	1·21918	13·1236	25·8055	·62002	·3716	43·057	65·545	·244108	·113261	141·266	1·81437	8·8185	·281238	56·891	5·9528	2·6878	4
5	1·52397	16·4045	32·2568	77·503	·4645	53·821	81·931	·305135	·141577	176·593	2·26796	11·0231	·351548	71·114	7·4410	3·3598	5
6	1·82877	19·6854	38·7082	·93004	·5574	64·586	98·317	·366162	·169892	211·899	2·72156	13·2277	·421857	85·337	8·9292	4·0317	6
7	2·13356	22·9663	45·1596	1·08504	·6503	75·35	114·703	·427189	·198267	247·216	3·17515	15·4323	·492167	99·56	10·4173	4·7037	7
8	2·43836	26·2472	51·6109	1·24005	·7432	86·114	131·089	·488216	·226522	282·533	3·62874	17·6370	·562476	113·783	11·9055	5·3757	8
9	2·74315	29·8562	58·0623	1·39505	·8361	96·879	147·476	·549243	·254838	317·849	4·08233	09·8416	·632786	128·005	13·3937	6·0476	9
10	3·04794	33·1371	64·5137	1·55006	·929	107·643	163·862	·610271	·283153	353·166	4·53593	22·0462	·703095	142·228	14·8819	6·7196	10

TABLE 41.—CONVERSION FACTORS.

English to Metrical.

Linear Measure.

Inches	× 25·39954	= millimetres.
Inches	× 2·539954	= centimetres.
Inches	× 0·02539954	= metres.
Feet	× 0·304795	= metres.
Yards	× 0·91438325	= metres.
Fathoms	× 1·82876696	= metres.
Links	× 0·20117	= metres.
Poles	× 5·02911	= metres.
Furlongs	× 201·16437	= metres.
Miles	× 1609·3146	= metres.
Miles	× 1·6093146	= kilometres.
Nautical miles	× 1855·020	= metres.
Nautical miles	× 1·855020	= kilometres.

Square Measure.

Sq. inches	× 6·45125	= sq. centimetres.
Sq. inches	× 0·000645125	= sq. metres.
Sq. feet	× 0·0928980	= sq. metres.
Sq. yards	× 0·8360820	= sq. metres.
Rods	× 25·291480	= sq. metres.
Roods	× 10·116750	= acres.
Acres	× 4046·71	= sq. metres.
Acres	× 0·404671	= hectares.
Sq. miles	× 2·58998	= sq. kilometres.
Sq. miles	× 258·998	= hectares.

Cubic Measure.

Cub. inches	× 16·3861759	= cub. centimetres.
Cub. feet	× 0·02831531	= cub. metres.
Cub. yards	× 0·764553	= cub. metres.

Weight.

Grains (troy)	× 0·0648	= grammes.
Pennyweights	× 1·5552	= grammes.
Drams	× 1·772	= grammes.
Ounces (troy)	× 31·1035	= grammes.

Weight—continued.

Ounces (avoir.)	× 28·3495	= grammes.
Pounds (troy)	× 373·220	= grammes.
Pounds (avoir.)	× 453·59265	= grammes.
Pounds (avoir.)	× 0·45359265	= kilogrammes.
Cwts.	× 50·802377	= kilogrammes.
Tons	× 1016·0475443	= kilogrammes.
Tons	× 1·0160475443	= tonnes.
Tons (American)	× 0·908	= tonnes.

Volume.

Pints	× 0·56825	= litres.
Quarts	× 1·13650	= litres.
Gallons	× 4·545963	= litres.
Bushels	× 36·3677	= litres.

METRICAL TO ENGLISH.

Linear Measure.

Millimetres	× 0·0393708	= inches.
Centimetres	× 0·393708	= inches.
Decimetres	× 3·93708	= inches.
Metres	× 39·37079	= inches.
Metres	× 3·2808992	= feet.
Metres	× 1·093633	= yards.
Kilometres	× 1093·633	= yards.
Kilometres	× 0·62137	= miles.
Myriametres	× 6·2138	= miles.

One Nœud = One Eng. nautical mile.

Square Measure.

Sq. millimetres	× 0·00155	= sq. inches.
Sq. centimetres	× 0·155	= sq. inches.
Sq. metres	× 10·7639	= sq. feet.
Sq. metres	× 1·193623	= sq. yards.
Ares	× 119·6	= sq. yards.
Ares	× 0·098845	= roods.
Hectares	× 2·471143	= acres.
Sq. kilometres	× 247·1143	= acres.

Cubic Measure.

Cub. centimetres	× 0·061027	= cub. inches.
Cub. decimetres	× 61·024	= cub. inches.
Cub. metres	× 35·31658074	= cub. feet.
Cub. metres	× 1·307954	= cub. yards.

Weight.

Milligrammes	× 0·015	= grains (troy).
Grammes	× 15·4323	= grains (troy).
Grammes	× 0·643	= pennyweights.
Grammes	× 0·03527	= ounces (avoir.).
Kilogrammes	× 15433·0	= grains (troy).
Kilogrammes	× 35·3	= ounces (avoir.).
Kilogrammes	× 2·679	= pounds (troy).
Kilogrammes	× 2·20462125	= pounds (avoir.).
Myriagrammes	× 22·0462125	= pounds (avoir.).
Quintals (100 kilos.)	× 220·462125	= pounds (avoir.).
Quintals	× 1·968	= cwts.
Tonnes (1,000 kilos.)	× 2204·62125	= pounds (avoir.).
Tonnes	× 0·9842	= tons (British).

Volume.

Litres (1,000 cu. cms.)	× 1·7598	= pints.
Litres	× 61·025385	= cub. metres.
Litres	× 0·22	= gallons.

COMPOUND CONVERSION FACTORS.

English to Metrical.

Weight and Length.

Pounds per foot	× 1·48817	= kilos. per metre.
Pounds per yard	× 0·49606	= kilos. per metre.
Pounds per mile	× 0·2818	= kilos. per kilometre.
Tons per foot	× 3333·33	= kilos. per metre.
Tons per yard	× 1111·11	= kilos. per metre.

Pressure and Area.

Pounds per sq. inch	× 0·00070	= kilos. per sq. millimetre.
Pounds per sq. inch	× 0·0703	= kilos. per sq. centimetre.
Tons per sq. inch	× 1·57488	= kilos. per sq. millimetre.
Tons per sq. inch	× 157·488	= kilos. per sq. centimetre.

Pressure and Area—continued.

Pounds per sq. foot	× 0·00049 =	kilos. per sq. centimetre.
Pounds per sq. foot	× 4·883 =	kilos. per sq. metre.
Tons per sq. foot	× 1·09367 =	kilos. per sq. centimetre.
Tons per sq. foot	× 10·9367 =	tonnes per sq. metre.
Tons per sq. yard	× 1·215 =	tonnes per sq. metre.

Weight and Volume.

Pounds per cub. foot	× 16·020 =	kilos. per cub. metre.
Pounds per cub. yard	× 0·5933 =	kilos. per cub. metre.
Tons per cub. yard	× 1·329 =	tonnes per cub. metre.
Grains per gallon	× 0·01426 =	grammes per litre.
Pounds per gallon	× 0·09983 =	kilos. per litre.
Tons per acre	× 2510·71 =	kilos. per hectare.

Volume and Area.

Gallons per sq. foot	× 48·905 =	litres per sq. metre.
Bushels per acre	× 0·89867 =	hectolitres per hectare.

Weight and Length.

Foot-pounds	× 0·13825 =	kilogram-metres.
Inch-tons	× 25·8076 =	kilogram-metres.
Foot-tons	× 309·691 =	kilogram-metres.

Horse-power.

Horse-power	× 1·0139 =	force de cheval.
Pounds per h.p.	× 0·477 =	kilos. per cheval.
Sq. feet per h.p.	× 0·0196 =	sq. metres per cheval.
Cub. feet per h.p.	× 0·0279 =	cub. metres per cheval.

Heat.

B.Th. Units	× 0·252 =	calories.
B.Th.Us. per sq. foot	× 2·713 =	calories per sq. metre.
Joules	× 0·24 =	gramme calories.

METRICAL TO ENGLISH.

Weight and Length.

Kilos. per metre	× 0·672 =	pounds per foot.
Kilos. per metre	× 2·016 =	pounds per yard.
Kilos. per metre	× 0·0003 =	tons per foot.
Kilos. per metre	× 0·0009 =	tons per yard.
Kilos. per kilometre	× 3·548 =	pounds per mile.

Pressure and Area.

Kilos. per sq. centimetre	× 14·223	= pounds per sq. inch.
Kilos. per sq. millimetre	× 0·635	= tons per sq. inch.
Kilos. per sq. metre	× 0·2048	= pounds per sq. foot.
Tonnes per sq. metre	× 0·0914	= tons per sq. foot.
Tonnes per sq. metre	× 0·8226	= tons per sq. yard.

Weight and Volume.

Kilos. per cub. metre	× 1·685	= pounds per cub. yard.
Kilos. per cub. metre	× 0·0624	= pounds per cub. yard.
Tonnes per cub. metre	× 0·752	= tons per cub. yard.
Grammes per litre	× 70·1	= grains per gallon.
Kilos. per litre	× 10·02	= pounds per gallon.

Volume and Area.

Litres per sq. metre	× 0·0204	= gallons per sq. foot.

Weight and Length.

Kilogram-metres	× 7·233	= foot-pounds.
Tonne-metres	× 3·09	= foot-tons.

Horse-power.

Force de cheval	× 0·9863	= horse-power.
Kilos. per cheval	× 2·235	= pounds per h.p.
Sq. metres per cheval	× 10·913	= sq. feet per h.p.
Cub. metres per cheval	× 35·806	= cub. feet per h.p.

Heat.

Calories	× 3·968	= B.Th. Units.
Calories per sq. metre	× 0·369	= B.Th.Us. per sq. foot.
Gramme-calories	× 4·187	= joules.

Velocity.

Kilometres per hour	× 0·91135	= feet per second.

TABLE 42. WIRE AND SHEET GAUGES.

The following Table gives the comparative sizes of wires and sheets in the more common gauges. The dimensions given are the diameters in inches.

Number of Wire Gauge.	Standard Wire Gauge, S.W.G.	Birmingham or Stubs, B.W.G.	American, or Brown & Sharpe, B. & S.	Birmingham Iron or Steel Sheets.	Birmingham Sheets, not Iron or Steel.	Birmingham Wire Gauge Precious Metals.	Warrington Wire Gauge.	Stubs' Steel Wire Gauge.	Whitworth's Wire Gauge.	Piano Wire Gauge.	U.S. Standard for Plates.	Number of Wire Gauge.
000000	·464	—	—	—	—	—	·469	—	—	—	·4688	000000
00000	·432	—	—	—	—	—	·437	—	—	—	·4375	00000
0000	·400	·454	·460	—	—	—	·400	—	—	—	·4063	0000
000	·372	·425	·4096	—	—	—	·375	—	—	—	·3750	000
00	·348	·380	·3648	—	—	—	·344	—	—	—	·3438	00
0	·324	·340	·3249	—	—	—	·326	—	—	—	·3125	0
1	·300	·300	·3893	·004	·3125	·004	·300	·227	·001	—	·2813	1
2	·276	·284	·2576	·005	·2813	·005	·274	·219	·002	—	·2656	2
3	·252	·259	·2294	·008	·2500	·008	·25	·212	·003	—	·2500	3
4	·232	·238	·2043	·010	·2344	·010	·229	·207	·004	—	·2344	4
5	·212	·220	·1809	·012	·2188	·012	·209	·204	·005	—	·2188	5
6	·192	·203	·1620	·013	·2031	·013	·191	·201	·006	—	·2031	6
7	·176	·180	·1443	·015	·1875	·015	·174	·199	·007	—	·1875	7
8	·160	·165	·1285	·016	·1719	·016	·159	·197	·008	—	·1719	8
9	·144	·148	·1144	·019	·1563	·019	·146	·194	·009	—	·1563	9
10	·128	·134	·1019	·021	·1406	·024	·133	·191	·010	—	·1406	10
11	·116	·120	·0907	·029	·1250	·029	·117	·188	·011	—	·1250	11
12	·104	·109	·0808	·034	·1125	·034	·100	·185	·012	·029	·1094	12
13	·092	·095	·0720	·036	·1000	·036	·090	·182	·013	·031	·0938	13
14	·080	·083	·0641	·041	·0875	·041	·079	·180	·014	·033	·0781	14
15	·072	·072	·0571	·047	·0750	·047	·069	·178	·015	·035	·0703	15
16	·064	·065	·0508	·051	·0625	·051	·0625	·175	·016	·037	·0625	16
17	·056	·058	·0453	·057	·0563	·057	·053	·172	·017	·039	·0563	17
18	·048	·049	·0403	·061	·0500	·061	·047	·168	·018	·041	·0500	18
19	·040	·042	·0359	·064	·0438	·064	·041	·164	·019	·043	·0438	19
20	·036	·035	·0320	·067	·0375	·067	·036	·161	·020	·045	·0375	20
21	·032	·032	·0285	·072	·0344	·072	·0315	·157	—	·047	·0344	21
22	·028	·028	·0253	·074	·0313	·074	·028	·155	·022	·052	·0313	22
23	·024	·025	·0226	·077	·0281	·077	—	·153	—	—	·0281	23
24	·022	·022	·0201	·082	·0250	·082	—	·151	·024	—	·0250	24
25	·020	·020	·0179	·095	·0234	·095	—	·148	—	—	·0219	25
26	·018	·018	·0159	·103	·0219	·103	—	·146	·026	—	·0188	26
27	·0164	·016	·0142	·113	·0203	·113	—	·143	—	—	·0172	27
28	·0148	·014	·0126	·120	·0188	·120	—	·139	·028	—	·0156	28
29	·0136	·013	·0113	·124	·0172	·124	—	·134	—	—	·0141	29
30	·0124	·012	·010	·126	·0156	·126	—	·127	·030	—	·0125	30
31	·0116	·010	·0089	·133	·0141	·133	—	·120	—	—	·0109	31
32	·0108	·009	·0079	·143	·0125	·143	—	·115	·032	—	·0102	32
33	·010	·008	·0071	·145	—	·145	—	·112	—	—	·0094	33
34	·0092	·007	·0063	·148	—	·148	—	·110	·034	—	·0086	34
35	·0084	·005	·0056	·158	—	·158	—	·108	—	—	·0078	35
36	·0076	·004	·0050	·167	—	·167	—	·106	·036	—	·0070	36
37	·0068	—	·0045	—	—	—	—	·103	—	—	·0066	37
38	·0060	—	·0040	—	—	—	—	·101	·038	—	·0063	38
39	·0052	—	·0035	—	—	—	—	·099	—	—	—	39
40	·0048	—	·0031	—	—	—	—	·097	·040	—	—	40
41	·0044	—	—	—	—	—	—	·095	—	—	—	41
42	·0040	—	—	—	—	—	—	·092	—	—	—	42
43	·0036	—	—	—	—	—	—	·088	—	—	—	43
44	·0032	—	—	—	—	—	—	·085	—	—	—	44
45	·0028	—	—	—	—	—	—	·081	·045	—	—	45
46	·0024	—	—	—	—	—	—	·079	—	—	—	46

N.B. To convert these dimensions to millimetres divide by ·03937.

Sectional area $\frac{\pi d^2}{4}$, where "d" is the diameter.

TABLE 43.—WIRE GAUGES.

The legal wire gauge for use in the United Kingdom is the Imperial Standard Wire Gauge (S.W.G.). This gauge is also in general use for the thickness of metal sheets. There are several other gauges in use, the more common being the Birmingham Wire Gauge (B.W.G.), the American or Brown and Sharpe Gauge (B. & S.G.), and the Stubs' Steel Wire Gauge.

The following Table gives the dimensions of the Imperial Standard Wire Gauge.

IMPERIAL STANDARD WIRE GAUGE.

S.W.G. Number.	Diameter.			Sectional Area.		S.G.W. Number.
	Actual Inches.	Approx. Inches.	m.m.	Square Inches.	Square m.m.	
000000	·464	$\frac{15}{32}$ −	11·78	·16909	108·989	000000
00000	·432	$\frac{7}{16}$ −	10·97	·14657	94·515	00000
0000	·400	$\frac{13}{32}$ −	10·16	·12566	81·073	0000
000	·372	$\frac{3}{8}$ −	0·45	·10868	70·139	000
00	·348	$\frac{11}{32}$ +	8·84	·09511	61·374	00
0	·324	$\frac{21}{64}$ −	8·23	·08244	53·197	0
1	·300	$\frac{19}{64}$ +	7·62	·07068	45·603	1
2	·276	$\frac{9}{32}$ −	7·01	·05983	38·595	2
3	·252	$\frac{1}{4}$ +	6·40	·04987	32·170	3
4	·232	$\frac{15}{64}$ −	5·89	·04227	27·247	4
5	·212	$\frac{7}{32}$ −	5·38	·03530	22·733	5
6	·192	$\frac{3}{16}$ +	4·88	·02895	18·705	6
7	·176	$\frac{11}{64}$ +	4·47	·02433	15·692	7
8	·160	$\frac{5}{32}$ +	4·06	·02011	12·970	8
9	·144	$\frac{9}{64}$ +	3·66	·01629	10·510	9
10	·128	$\frac{1}{8}$ +	3·25	·01287	8·303	10
11	·116	$\frac{7}{64}$ +	2·95	·01057	6·819	11
12	·104	$\frac{7}{64}$ −	2·64	·00849	5·480	12
13	·092	$\frac{3}{32}$ +	2·34	·00665	4·289	13
14	·080	$\frac{5}{64}$ +	2·03	·00503	3·243	14
15	·072	$\frac{5}{64}$ −	1·83	·00407	2·627	15
16	·064	$\frac{1}{16}$ +	1·63	·00322	2·075	16
17	·056	$\frac{1}{16}$ −	1·42	·00246	1·589	17
18	·048	$\frac{3}{64}$ +	1·22	·00181	1·168	18
19	·040	$\frac{3}{64}$ −	1·016	·001256	·8109	19
20	·036	$\frac{1}{32}$ +	·914	·001018	·6567	20
21	·032	$\frac{1}{32}$ +	·813	·000804	·5188	21
22	·028	$\frac{1}{32}$ −	·711	·000616	·3973	22
23	·024	$\frac{1}{32}$ −	·610	·000452	·2919	23
24	·022	$\frac{1}{64}$ +	·559	·000380	·2453	24
25	·020	$\frac{1}{64}$ +	·508	·000314	·2027	25
26	·018	$\frac{1}{64}$ +	·457	·000254	·1642	26
27	·0164	$\frac{1}{64}$ +	·417	·000211	·13628	27
28	·0148	$\frac{1}{64}$ −	·376	·000172	·11099	28
29	·0136	$\frac{1}{64}$ −	·345	·000145	·093722	29
30	·0124	$\frac{1}{64}$ −	·315	·000121	·077910	30
31	·0116	—	·295	·000106	·068181	31
32	·0108	—	·274	·0000916	·059102	32
33	·0100	—	·254	·0000785	·050670	33
34	·0092	—	·234	·0000665	·042887	34
35	·0084	—	·213	·0000554	·035752	35
36	·0076	—	·193	·0000454	·029267	36
37	·0068	—	·173	·0000363	·023430	37
38	·0060	—	·152	·0000283	·018241	38
39	·0052	—	·132	·0000212	·013701	39
40	·0048	—	·122	·0000181	·011674	40

SCREW THREADS.

British Association Standard Thread (B.S.A.).

Angle of thread $47\frac{1}{2}$ degrees.

Cut away top and bottom $\frac{1}{8}$ of pitch.

Top and bottom rounded to a radius of $\frac{2}{11}$ pitch.

British Standard Whitworth Thread.

Angle of thread 55 degrees.

$$\text{Pitch} = \frac{1}{\text{number of threads per inch}}.$$

Depth = pitch × ·64033.

Radius top and bottom = pitch × ·1373.

Cut away top and bottom $\frac{1}{6}$ of the V made by the angle 55 degrees.

Square Thread (Single, Double and Treble).

In the single thread the depth of thread and thickness are usually half the pitch.

The double and treble threads are worked into the space taken for the pitch of the single thread.

They are generally used to transmit motion.

Acme Thread.

As the square threads are difficult to cut, this thread is often used in its stead.

Angle between the sides 29 degrees.

$$\text{Pitch} = \frac{1}{\text{number of threads per inch}}.$$

Depth of thread = half-pitch.

A clearance of ·01 is allowed top and bottom in all sizes.

American Standard Threads (Seller's).

Angle of thread 60 degrees.

Top and bottom cut flat $\frac{1}{8}$ pitch wide.

$$\text{Pitch} = \frac{1}{\text{number of threads per inch}}.$$

Depth = pitch × ·6495.

International Standard Thread (Metric System).

Same as Seller's thread except that bottom is rounded to $\frac{1}{8}$ pitch instead of flat.

Cycle Engineers' Standard Thread.

Angle of thread 60 degrees.

Cut away top and bottom and rounded to a radius of $\frac{1}{6}$ pitch.

NUTS AND BOLTS.

Whitworth Standard Bolt Heads.

Across flats $=$ ⎫ dimensions given in Table.
,, corners $=$ ⎭

Thickness $= \frac{7}{8}$ diameter.

Whitworth Standard Nuts.

Flats and corners same as head.

Thickness $=$ diameter.

Standard Thin Lock Nuts.

Flats and corners same as head.

Thickness $\frac{2}{3}$ thickness of standard nut.

British Standard Heads for Small Screws.

Diameter $= 1{\cdot}75$ diameter over thread.

Thickness varies according to purpose required.

American Standard Bolt Heads and Nuts (Seller's).

Across flats $= 1\frac{1}{2}$ diameter $+ \frac{1}{16}$ inch.

Thickness $= 1$ diameter $+ \frac{1}{16}$ inch.

Standard Castle Nut.

Total height $= 1{\cdot}25$ diameter of thread.

Height of hexagonal portion $= {\cdot}75$ diameter.

Diameter of cylindrical portion $=$ width across flats $- \frac{1}{16}$ inch.

Cylindrical portion to have 6 slots ${\cdot}4375$ diameter deep.

mm. = ·03937 inch. Sq. mm. = ·00155 sq. inch. Inch = 25·39954 mm.
Sq. inch = 645·1 sq. mm.

TABLE 44.—BRITISH ASSOCIATION THREADS.

Number.	Diameters. Actual in mm.	Diameters. Approx. in inches.	Diameters. Nearest Fraction Equivalent.	Diameters. Effective mm.	Diameters. Core m.m.	Core Area. Sq. mm.	Pitch. Actual in mm.	Pitch. Approx. in inches.	Depth of Thread in mm.	Number of Threads per inch.	Number.
0	6·0	·236	15/64 +	5·4	4·8	18·10	1·0	·0394	·6	25·4	0
1	5·3	·209	13/64 +	4·76	4·22	13·99	·9	·0354	·54	28·2	1
2	4·7	·185	3/16 —	4·215	3·73	10·93	·81	·0319	·485	31·4	2
3	4·1	·161	5/32 +	3·66	3·22	8·14	·73	·0287	·44	34·8	3
4	3·6	·142	9/64 +	3·205	2·81	6·20	·66	·026	·395	38·5	4
5	3·2	·126	1/8 +	2·845	2·49	4·87	·59	·0232	·355	43	5
6	2·8	·110	7/64 +	2·48	2·16	3·66	·53	·0209	·32	47·9	6
7	2·5	·098	3/32 +	2·21	1·92	2·89	·48	·0189	·29	52·9	7
8	2·2	·087	3/32 —	1·94	1·68	2·22	·43	·0169	·26	59·1	8
9	1·9	·075	5/64	1·665	1·43	1·61	·39	·0154	·235	65·1	9
10	1·7	·067	5/64 —	1·49	1·28	1·29	·35	·0138	·21	72·6	10
11	1·5	·059	1/16 —	1·315	1·13	1·00	·31	·0122	·185	81·9	11
12	1·3	·051	3/64 +	1·13	·96	·72	·28	·011	·17	90·7	12
13	1·2	·047	3/64	1·05	·9	·64	·25	·0098	·15	101	13
14	1·0	·039	3/64 —	·86	·72	·41	·23	·0091	·14	110	14
15	·9	·035	1/32 +	·775	·65	·33	·21	·0083	·125	121	15
16	·79	·031	1/32	·675	·56	·25	·19	·0075	·115	134	16
17	·70	·028	1/32 —	·6	·50	·20	·17	·0067	·10	149	17
18	·62	·024	—	·53	·44	·15	·15	·0059	·09	169	18
19	·54	·021	—	·455	·37	·11	·14	·0055	·085	181	19
20	·48	·019	—	·41	·34	·091	·12	·0047	·07	212	20
21	·42	·017	—	·355	·29	·066	·11	·0043	·065	231	21
22	·37	·015	1/64	·31	·25	·049	·10	·0039	·06	259	22
23	·33	·013	—	·275	·22	·038	·09	·0035	·055	285	23
24	·29	·011	—	·24	·19	·028	·08	·0031	·05	317	24
25	·25	·010	—	·21	·17	·023	·07	·0028	·04	353	25

TABLE 45.—BRITISH STANDARD WHITWORTH BOLTS.

Diameters. Full. Fraction.	Diameters. Full. Decimal.	Diameters. Effective.	Diameters. Core.	Core Area. Sq. ins.	Depth of Thread.	Pitch.	Threads per inch.	Hexagon Head. Flats.	Hexagon Head. Corners.	Hexagon Head. Height.	Nut. Height.	Standard Lock Nut. Height.	Diameter.
1/4	·25	·2180	·186	·0272	·032	·05	20	·525	·6062	·2187	·25	·17	1/4
5/16	·3125	·2769	·2414	·0458	·0356	·0556	18	·6014	·6944	·2734	·3125	·21	5/16
3/8	·375	·335	·295	·0683	·04	·0625	16	·7094	·8191	·3281	·375	·25	3/8
7/16	·4375	·3918	·346	·094	·0457	·0714	14	·8204	·9473	·3828	·4375	·29	7/16
1/2	·5	·4466	·3933	·1215	·0534	·0833	12	·9191	1·0612	·4375	·5	·33	1/2
9/16	·5625	·5091	·4558	·1632	·0534	·0833	12	1·011	1·1674	·4921	·5625	·38	9/16
5/8	·625	·5668	·5086	·2032	·0582	·0909	11	1·101	1·2713	·5468	·625	·42	5/8
11/16	·6875	·6293	·5711	·2562	·0582	·0909	11	1·2011	1·3869	·6015	·6875	·46	11/16
3/4	·75	·686	·6219	·3038	·064	·1	10	1·3012	1·5024	·6562	·75	·50	3/4
13/16	·8125	·7485	·6844	·3679	·064	·1	10	1·39	1·605	·7109	·8125	·54	13/16
7/8	·875	·8039	·7327	·4216	·0711	·1111	9	1·4788	1·7075	·7656	·875	·58	7/8
1	1·0	·92	·8399	·554	·08	·125	8	1·6701	1·9284	·875	1·0	·67	1
1 1/8	1·125	1·0335	·942	·6969	·0915	·1429	7	1·8605	2·1483	·9843	1·125	·75	1 1/8
1 1/4	1·25	1·1585	1·067	·8942	·0915	·1429	7	2·0483	2·3651	1·0937	1·25	·83	1 1/4
1 3/8	1·375	1·2683	1·1616	1·0597	·1067	·1667	6	2·2146	2·5571	1·2031	1·375	·92	1 3/8
1 1/2	1·5	1·3933	1·2866	1·3001	·1067	·1667	6	2·4134	2·7867	1·3125	1·5	1·0	1 1/2
1 5/8	1·625	1·4969	1·3689	1·4718	·1281	·2	5	2·5763	2·9748	1·4218	1·625	1·08	1 5/8
1 3/4	1·75	1·6219	1·4939	1·7528	·1281	·2	5	2·7578	3·0844	1·5312	1·75	1·17	1 3/4
2	2·0	1·8577	1·7154	2·3111	·1423	·2222	4·5	3·1491	3·6362	1·75	2·0	1·33	2
2 1/4	2·25	2·0899	1·9298	2·9249	·1601	·25	4	3·546	4·0945	1·9687	2·25	1·25	2 1/4
2 1/2	2·5	2·3399	2·1798	3·7318	·1601	·25	4	3·894	4·4964	2·1875	2·5	1·67	2 1/2
2 3/4	2·75	2·567	2·3841	4·4641	·183	·2857	3·5	4·181	4·8278	2·4062	2·75	1·83	2 3/4
3	3·0	2·817	2·6341	5·4496	·183	·2857	3·5	4·531	5·2319	2·625	3·0	2·0	3
3 1/4	3·25	3·053	2·856	6·4063	·197	·3077	3·25	4·85	5·6002	2·843	3·25	2·17	3 1/4
3 1/2	3·5	3·303	3·106	7·5769	·197	·3077	3·25	5·175	5·9755	3·062	3·5	2·33	3 1/2
3 3/4	3·75	3·5366	3·3231	8·6732	·2134	·3333	3	5·55	6·4085	3·218	3·75	2·50	3 3/4
4	4·0	3·7866	3·5731	10·0272	·2134	·3333	3	5·95	6·8704	3·5	4·0	2·67	4
4 1/2	4·5	4·2773	4·0546	12·9118	·2227	·3478	2·875	6·825	7·8819	3·937	4·5	3·0	4 1/2
5	5·0	4·7672	4·5343	16·1477	·2328	·3636	2·75	7·8	9·0066	4·375	5·0	3·33	5
5 1/2	5·5	5·2561	5·0121	19·7301	·2439	·381	2·625	8·85	10·219	4·812	5·5	3·67	5 1/2
6	6·0	5·7439	5·4877	23·6521	·2561	·4	2·5	10·0	11·547	5·25	6·0	4·0	6

TABLE 46.—BRITISH STANDARD FINE SCREW THREADS.

Diameters.				Core Area Sq. ins.	Depth of Thread.	Pitch.	Threads per Inch.	Diameter.
Full Fraction.	Full Decimal.	Effective.	Core					
1/4	·25	·2244	·1988	·031	·0256	·04	25	1/4
5/16	·3125	·2834	·2543	·0508	·0291	·0455	22	5/16
3/8	·375	·3430	·311	·076	·032	·05	20	3/8
7/16	·4375	·4019	·3664	·1054	·0356	·0556	18	7/16
1/2	·5	·46	·42	·1385	·04	·0625	16	1/2
9/16	·5625	·5225	·4825	·1828	·04	·0625	16	9/16
5/8	·625	·5793	·5335	·2235	·0457	·0714	14	5/8
11/16	·6875	·6418	·596	·279	·0457	·0714	14	11/16
3/4	·75	·6966	·6433	·325	·0534	·0833	12	3/4
13/16	·8125	·7591	·7058	·3913	·0534	·0833	12	13/16
7/8	·875	·8168	·7586	·452	·0582	·0909	11	7/8
1	1·0	·936	·8719	·5971	·064	·1	10	1
1 1/8	1·125	1·0539	·9827	·7585	·0711	·1111	9	1 1/8
1 1/4	1·25	1·1789	1·1077	·9637	·0711	·1111	9	1 1/4
1 3/8	1·375	1·295	1·2149	1·1593	·08	·125	8	1 3/8
1 1/2	1·5	1·42	1·3399	1·41	·08	·125	8	1 1/2
1 5/8	1·625	1·545	1·4649	1·6854	·08	·125	8	1 5/8
1 3/4	1·75	1·6585	1·567	1·9285	·0915	·1429	7	1 3/4
2	2·0	1·9085	1·817	2·593	·0915	·1429	7	2
2 1/4	2·25	2·1433	2·0366	3·2576	·1067	·1667	6	2 1/4
2 1/2	2·5	2·3933	2·2866	4·1065	·1067	·1667	6	2 1/2
2 3/4	2·75	2·6433	2·5366	5·0535	·1067	·1667	6	2 3/4
3	3·0	2·8719	2·7439	5·9133	·1281	·2	5	3
3 1/4	3·25	3·1219	2·9939	7·0399	·1281	·2	5	3 1/4
3 1/2	3·5	3·3577	3·2154	8·1201	·1423	·2222	4·5	3 1/2
3 3/4	3·75	3·6077	3·4654	9·4319	·1423	·2222	4·5	3 3/4
4	4·0	3·8577	3·7154	10·8418	·1423	·2222	4·5	4
4 1/2	4·5	4·3399	4·1798	13·7215	·1601	·25	4	4 1/2
5	5·0	4·8399	4·6798	17·2006	·1601	·25	4	5
5 1/2	5·5	5·317	5·1341	20·7023	·183	·2857	3·5	5 1/2
6	6·0	5·817	5·6341	24·931	·183	·2857	3·5	6

TABLE 47.—AMERICAN STANDARD SELLERS THREADS.

Diameter.			Pitch. Inches.	Pitch. m.m.	Width of Flat. Inches.	Tapping Hole.	Threads per Inch.	Diameter.
Full Fraction.	Full Decimal.	Core.						
1/4	·25	·185	·05	1·27	·0062	3/16	20	1/4
5/16	·3125	·24	·0555	1·41	·0069	1/4	18	5/16
3/8	·375	·294	·0625	1·587	·0078	19/64	16	3/8
7/16	·4375	·345	·0714	1·814	·0089	23/64	14	7/16
1/2	·5	·4	·0769	1·95	·0096	13/32	31	1/2
9/16	·5625	·454	·0833	2·116	·0104	15/32	12	9/16
5/8	·625	·506	·0909	2·39	·0114	33/64	11	5/8
3/4	·75	·62	·1	2·54	·0125	5/8	10	3/4
7/8	·875	·731	·1111	2·822	·0139	47/64	9	7/8
1	1·0	·837	·125	3·175	·0156	27/32	8	1
1 1/8	1·125	·939	·1428	3·628	·0178	61/64	7	1 1/8
1 1/4	1·25	1·064	·1428	3·628	·0178	1 5/64	7	1 1/4
1 3/8	1·375	1·158	·1666	4·233	·0208	1 11/64	6	1 3/8
1 1/2	1·5	1·283	·1666	4·233	·0208	1 19/64	6	1 1/2
1 5/8	1·625	1·389	·1818	4·62	·0227	1 25/64	5 1/2	1 5/8
1 3/4	1·75	1·49	·2	5·08	·025	1 1/2	5	1 3/4
1 7/8	1·875	1·615	·2	5·08	·025	1 5/8	5	1 7/8
2	2·0	1·711	·2222	5·644	·0277	1 23/32	4 1/2	2
2 1/4	2·25	1·961	·2222	5·644	·0277	1 31/32	4 1/2	2 1/4

TABLE 47.—AMERICAN STANDARD SELLERS THREADS—*continued.*

Diameter. Full Fraction.	Diameter. Full Decimal.	Core.	Pitch. Inches.	Pitch. m.m.	Width of Flat. Inches.	Tapping Hole.	Threads per Inch.	Diameter.
2 1/2	2·5	2·175	·25	6·35	·0313	2 3/16	4	2 1/2
2 3/4	2·75	2·425	·25	6·35	·0313	2 7/16	4	2 3/4
3	3·0	2·628	·2857	7·257	·0357	2 21/32	3 1/2	3
3 1/4	3·25	2·878	·2857	7·257	·0357	2 57/64	3 1/2	3 1/4
3 1/2	3·5	3·1	·3077	7·815	·0384	3 7/64	3 1/4	3 1/2
3 3/4	3·75	3·317	·3333	8·466	·0416	3 21/64	3	3 3/4
4	4·0	3·567	·3333	8·466	·0416	3 37/64	3	4
4 1/4	4·25	3·798	·3478	8·834	·0434	3 13/16	2 7/8	4 1/4
4 1/2	4·5	4·027	·3636	9·236	·0454	4 1/32	2 3/4	4 1/2
4 3/4	4·75	4·255	·3809	9·676	·0478	4 17/64	2 5/8	4 3/4
5	5·0	4·48	·4	10·16	·05	4 31/64	2 1/2	5
5 1/4	5·25	4·73	·4	10·16	·05	4 47/64	2 1/2	5 1/4
5 1/2	5·5	4·953	·421	10·68	·0526	4 61/64	2 3/8	5 1/2
5 3/4	5·75	5·203	·421	10·68	·0526	5 13/64	2 3/8	5 3/4
6	6·0	5·423	·444	11·29	·0555	5 7/16	2 1/4	6

TABLE 48. ACME STANDARD THREADS.

Threads per Inch.	Depth of Thread. Inches.	Width at Top.	Width at Bottom.	Thickness at Root.	Pitch. Inches.
1	·51	·3707	·3655	·6345	1·0
1 1/2	·3433	·2471	·2419	·4247	·6666
2	·26	·1853	·1801	·3199	·5
3	·1767	·1235	·1183	·215	·3333
4	·135	·0927	·0875	·1625	·25
5	·11	·0741	·0689	·1311	·2
6	·0933	·0618	·0566	·1101	·1667
7	·0814	·0529	·0478	·0951	·1428
8	·0725	·0463	·0411	·0839	·125
9	·0655	·0413	·0361	·0751	·1112
10	·06	·0371	·0319	·0681	·1

TABLE 49.

SCREW THREADS FOR GAS AND WATER PIPES.

The dimensions of threads for pipes adopted by the Engineering Standards Committee differs slightly in some cases from the older and more generally used Whitworth Gas Threads. The accompanying Table gives the relative sizes of the two.

BRITISH STANDARD PIPE THREADS AND WHITWORTH GAS THREADS.

Internal Diameter of Pipe.	Diameter over Thread. Inches.		Diameter at Bottom of Thread. Inches.		No. of Threads per Inch.		Internal Diameter of Pipe.
	British Standard Thread.	Whitworth Gas Thread.	British Standard Thread.	Whitworth Gas Thread.	British Standard Thread.	Whit-worth Gas Thread.	
1/8	·383	·382	·337	·336	28	28	1/8
1/4	·518	·518	·451	·451	19	19	1/4
3/8	·656	·656	·589	·589	19	19	3/8
1/2	·825	·826	·734	·734	14	14	1/2
5/8	·902	·902	·811	·811	14	14	5/8
3/4	1·041	1·040	·950	·949	14	14	3/4
7/8	1·189	1·189	1·098	1·097	14	14	7/8
1	1·309	1·309	1·193	1·192	11	11	1
1 1/4	1·650	1·650	1·534	1·533	11	11	1 1/4
1 1/2	1·882	1·882	1·766	1·765	11	11	1 1/2
1 3/4	2·116	2·047	2·000	1·930	11	11	1 3/4
2	2·347	2·347	2·231	2·230	11	11	2
2 1/4	2·587	2.587	2·471	2·470	11	11	2 1/4
2 1/2	2·96	3.000	2·844	2·882	11	11	2 1/2
2 3/4	3·21	3·247	3·094	3·130	11	11	2 3/4
3	3·46	3·485	3·344	3·368	11	11	3
3 1/4	3·70	3·698	3·584	3·581	11	11	3 1/4
3 1/2	3·95	3·912	3·834	3·795	11	11	3 1/2
3 3/4	4·20	4·125	4·084	4·008	11	11	3 3/4
4	4·45	4·340	4·334	4·223	11	11	4
4 1/2	4·95	—	4·834	—	11	—	4 1/2
5	5·45	—	5·334	—	11	—	5
5 1/2	5·95	—	5·834	—	11	—	5 1/2
6	6·45	—	6·334	—	11	—	6
7	7·45	—	7·322	—	10	—	7
8	8·45	—	8·322	—	10	—	8
9	9·45	—	9·322	—	10	—	9
10	10·45	—	10·322	—	10	—	10
11	11·45	—	11·29	—	8	—	11
12	12·45	—	12·29	—	8	—	12
13	13·68	—	13·52	—	8	—	13
14	14·68	—	14·52	—	8	—	14
15	15·68	—	15·52	—	8	—	15
16	16·68	—	16·52	—	8	—	16
17	17·68	—	17·52	—	8	—	17
18	18·68	—	18·52	—	8	—	18

WOOD SCREWS.

Wood screws are usually made with countersunk, raised, or round heads as shown, and of lengths between $\frac{1}{8}$ in. and 7 ins. The dimensions given in the Table are the usual standards adopted, and screws are made to these proportions by Nettlefold's Department of Messrs. Guest, Keen and Nettlefolds, Ltd.

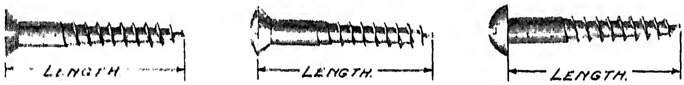


TABLE 50.

Gauge No.	Diameter in Inches. Actual.	Diameter in Inches. Approx.	Threads per Inch. Approx.	Nearest French or Paris Gauge.	Length. Inches.	Ga
0000	·054	$\frac{3}{64}$ +	38	—	$\frac{1}{8}$	4/0 to 2
000	·057	$\frac{1}{16}$ −	36	10	$\frac{3}{16}$	4/0 „ 4
00	·060	$\frac{1}{16}$ −	34	—	$\frac{1}{4}$	4/0 „ 8
0	·063	$\frac{1}{16}$ +	32	11	$\frac{5}{16}$	0 „ 6
1	·066	$\frac{5}{64}$ −	28	12	$\frac{3}{8}$	4/0 „ 10
2	·080	$\frac{5}{64}$ +	26	14	$\frac{7}{16}$	2 „ 8
3	·094	$\frac{3}{32}$ +	24	16	$\frac{1}{2}$	3/0 „ 14
4	·108	$\frac{7}{64}$ −	22	17	$\frac{5}{8}$	2/0 „ 16
5	·122	$\frac{1}{8}$ −	20	18	$\frac{3}{4}$	2/0 „ 16
6	·136	$\frac{9}{64}$ −	18	19	1	1 „ 24
7	·150	$\frac{5}{32}$ −	16	20	$1\frac{1}{8}$	4 „ 16
8	·164	$\frac{11}{64}$ −	15	20	$1\frac{1}{4}$	2 „ 30
9	·178	$\frac{11}{64}$ +	14	21	$1\frac{1}{2}$	2 „ 32
10	·192	$\frac{3}{16}$ +	13	21	$1\frac{3}{4}$	2 „ 32
11	·206	$\frac{13}{64}$ +	12	22	2	2 „ 40
12	·220	$\frac{7}{32}$ +	11	23	$2\frac{1}{4}$	3 „ 32
13	·234	$\frac{15}{64}$	11	23	$2\frac{1}{2}$	3 „ 40
14	·248	$\frac{1}{4}$ −	10	24	$2\frac{3}{4}$	6 „ 32
15	·262	$\frac{17}{64}$ −	10	24	3	4 „ 40
16	·276	$\frac{9}{32}$ −	9	25	$3\frac{1}{4}$	10 „ 24
17	·290	$\frac{19}{64}$ −	8	25	$3\frac{1}{2}$	6 „ 40
18	·304	$\frac{5}{16}$ −	8	26	$3\frac{3}{4}$	14 and 16
20	·332	$\frac{21}{64}$ +	7	27	4	8 to 40
22	·360	$\frac{23}{64}$ +	7	28	$4\frac{1}{2}$	8 „ 40
24	·388	$\frac{25}{64}$ −	6	29	5	10 „ 40
26	·416	$\frac{27}{64}$ −	6	30	$5\frac{1}{2}$	12 „ 32
28	·444	$\frac{7}{16}$ +	6	—	6	10 „ 40
30	·472	$\frac{15}{32}$ +	6	—	7	18 „ 40
32	·500	$\frac{1}{2}$	6	—	—	—

NOTE.—Screws of $3\frac{1}{2}$ ins., $5\frac{1}{2}$ ins., 6 ins., and 7 ins., are made in even gauges only.

WEIGHT.

The following Table gives the approximate weight of countersunk headed iron wood screws of the sizes most commonly used.

TABLE 51.

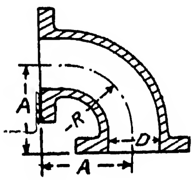
WEIGHT OF IRON WOOD SCREWS. LBS. (AVOIR.) PER GROSS.

Gauge	Length. Inches.															
No.	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3½
1	·027	·05	·06	·08												
2	·05	·06	·08	·11												
3	·07	·09	·12	·15												
4	·10	·12	·16	·19	·24	·31	·38									
5	·12	·16	·22	·25	·30	·39	·47									
6	·16	·21	·25	·33	·40	·48	·57	·65	·75	·87	1·00	1·05	1·15			
7	—	·25	·33	·41	·49	·57	·64	·73	·88	1·00	1·20	1·30	1·50			
8	—	·30	·42	·49	·58	·67	·75	·88	1·10	1·15	1·42	1·55	1·75	1·85	2·00	
9	—	·36	·50	·59	·69	·78	·90	1·03	1·20	1·42	1·60	1·80	2·05	2·20	2·40	
10	—	·47	·60	·70	·81	·92	1·04	1·18	1·37	1·56	1·85	2·00	2·40	3·50	2·75	3·00
11	—	—	·66	·80	·93	1·05	1·19	1·40	1·60	1·83	2·08	2·30	2·70	3·10	3·20	3·50
12	—	—	·75	·90	1·07	1·20	1·35	1·60	1·83	2·06	2·35	2·65	3·10	3·45	3·60	4·00
13	—	—	—	—	—	1·35	1·52	1·80	2·10	2·40	2·70	3·05	3·45	3·80	4·00	4·70
14	—	—	—	—	—	1·54	1·75	2·10	2·45	2·75	3·10	3·45	3·80	4·10	4·75	5·50
16	—	—	—	—	—	—	2·15	2·50	3·05	3·50	3·90	4·10	4·70	5·10	5·50	6·50
18	—	—	—	—	—	—	2·80	3·20	3·75	4·25	4·80	5·10	5·80	6·25	7·00	8·00
20	—	—	—	—	—	—	3·50	4·00	4·50	5·20	5·80	6·30	7·10	7·70	8·25	9·50
22	—	—	—	—	—	—	—	—	—	6·40	7·00	7·50	8·50	9·00	10·25	11·25
24	—	—	—	—	—	—	—	—	—	7·25	8·20	9·00	10·00	11·25	12·50	13·75

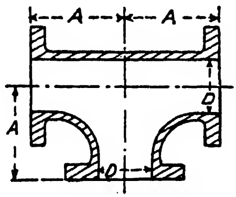
PIPE BENDS AND TEES.

The dimensions given in the following Table are those adopted by the Engineering Standards Committee for cast metal short bends and tees, and for long bends of wrought iron and steel.

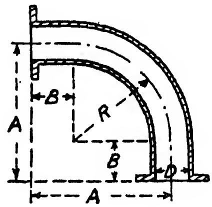
In the case of short bends and tees it will be noticed that the dimension from the centre of the bore to the face of the flange (A) is always greater by 3 ins. than the bore of the pipe.



SHORT BEND.



TEE.



LONG BEND.

TABLE 52.

D. Internal Dia. of Pipe. Inches.	Short Bend. A. Centre to Flange Face.	Short Bend. R. Radius of Centre Line.	Tee. A. Centre to Flange Face.	Tee. R. Radius of Centre Line.	Long Bend. A. Centre to Flange Face.	Long Bend. R. Radius of Centre Line	Long Bend. B. Length of Straight.	D. Internal Dia. of Pipe. Inches.
½	3½	2½	3½	2½	4½	2	2½	½
¾	3¾	2¾	3¾	2¾	5	2½	2½	¾
1	4	2¾	4	2¾	6	3	3	1
1¼	4¼	3	4¼	3	6¾	3¾	3	1¼
1½	4½	3	4½	3	7½	4½	3	1½
2	5	3¼	5	3¼	9½	6	3½	2
2½	5½	3¾	5½	3¾	11½	7½	4	2½
3	6	4	6	4	13	9	4	3
3½	6½	4½	6½	4½	15½	10½	5	3½
4	7	4¾	7	4¾	17	12	5	4
5	8	5½	8	5½	21	15	6	5
6	9	6½	9	6½	25	18	7	6
7	10	7¼	10	7¼	31½	24½	7	7
8	11	8¼	11	8¼	36	28	8	8
9	12	9	12	9	39½	31½	8	9
10	13	10	13	10	49	40	9	10
12	15	11¾	15	11¾	58	48	10	12
14	17	13½	17	13½	74	63	11	14
16	19	15¼	19	15¼	93	80	13	16
18	21	17	21	17	104	90	14	18
20	23	18¾	23	18¾	126	110	16	20

PIPE FLANGES.

The following Tables give the dimensions of pipe flanges that have been adopted by the Engineering Standards Committee. Table 53 gives the dimensions of flanges for working steam pressures up to 55 lbs. per square inch, and for water pressures up to 200 lbs. per square inch. Table 54 gives the dimensions of flanges for steam pressures up to 325 lbs. per square inch.

TABLE 53.—BRITISH STANDARD PIPE FLANGES.

FOR WORKING STEAM PRESSURES UP TO 55 LBS. PER SQ. IN. AND WATER PRESSURES UP TO 200 LBS. PER SQ. IN.

Internal Dia. of Pipe.	Thickness of Flange.			Dia. of Flange.	Dia. of Bolt Circle.	Number of Bolts.	Size of Bolts.	Dia. of Bolt Holes.	Internal Dia of Pipe.
	Cast Iron, and Steel or Iron Welded on.	Cast Steel or Bronze.	Stamped or Forged Wrought Iron or Steel.						
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.
½	½	⅜	3/16	3¾	2⅝	4	½	9/16	½
¾	½	⅜	3/16	4	2⅞	4	½	9/16	¾
1	½	⅜	3/16	4½	3¼	4	½	9/16	1
1¼	⅝	½	¼	4¾	3 7/16	4	½	9/16	1¼
1½	⅝	½	¼	5¼	3⅞	4	½	9/16	1½
2	¾	9/16	5/16	6	4½	4	⅝	11/16	2
2½	¾	9/16	5/16	6½	5	4	⅝	11/16	2½
3	¾	9/16	⅜	7¼	5¾	4	⅝	11/16	3
3½	¾	9/16	⅜	8	6½	4	⅝	11/16	3½
4	⅞	11/16	⅜	8½	7	4	⅝	11/16	4
5	⅞	11/16	½	10	8¼	8	⅝	11/16	5
6	⅞	11/16	½	11	9¼	8	⅝	11/16	6
7	1	¾	½	12	10¼	8	⅝	11/16	7
8	1	¾	⅝	13¼	11¼	8	⅝	11/16	8
9	1	¾	⅝	14¼	12¼	8	⅝	11/16	9
10	1	¾	⅝	16	14	8	⅝	11/16	10
12	1⅛	⅞	⅝	18	16	12	¾	⅞	12
14	1¼	1	¾	20¾	18½	12	¾	1	14
15	1¼	1	¾	21¾	19½	12	⅞	1	15
16	1¼	1	¾	22¾	20½	12	⅞	1	16
18	1⅜	1⅛	⅞	25¼	23	12	⅞	1	18
20	1½	1¼	1	27¾	25¼	16	⅞	1	20
21	1½	1¼	1	29	26½	16	⅞	1	21
24	1½	1⅜	1⅛	32½	29¾	16	1	1⅛	24

TABLE 54.—BRITISH STANDARD PIPE FLANGES.

FOR WORKING STEAM PRESSURES UP TO 325 LBS. PER SQ. IN.

Internal Dia. of Pipe.	Thickness of Flange.						Pressures to 325 lbs.			Up to 225 lbs. Pressure.		225 to 325 lbs. Pressure.		Internal Dia. of Pipe.
	Cast Iron, and Steel or Iron Welded on.			Steel, Cast or Riveted on, or Bronze.										
	Up to 125 lbs. pressure.	126 to 225 lbs. pressure.	226 to 325 lbs. pressure.	Up to 125 lbs. pressure.	126 to 225 lbs. pressure.	226 to 325 lbs. pressure.	Dia. of Flange.	Dia. of Bolt Circle.	Number of Bolts.	Dia of Bolts.	Dia. of Bolt Holes.	Dia. of Bolts.	Dia. of Bolt Holes.	
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.	Inches.	Inches.
½	½	½	⅝	⅜	7/16	⅝	3¾	2⅝	4	½	9/16	½	9/16	½
¾	½	½	⅝	⅜	7/16	⅝	4	2⅞	4	½	9/16	½	9/16	¾
1	⅝	⅝	¾	⅜	½	11/16	4¾	3 7/16	4	⅝	11/16	⅝	11/16	1
1¼	⅝	⅝	¾	½	½	11/16	5¼	3⅞	4	⅝	11/16	⅝	11/16	1¼
1½	⅝	¾	⅞	½	9/16	¾	5½	4⅛	4	⅝	11/16	⅝	11/16	1½
2	¾	⅞	1	⅝	11/16	⅞	6½	5	4	⅝	11/16	¾	⅞	2
2½	¾	⅞	1	⅝	11/16	⅞	7¼	5¾	8	⅝	11/16	¾	⅞	2½
3	¾	1	1¼	⅝	¾	1	8	6½	8	⅝	11/16	¾	⅞	3
3½	⅞	1	1¼	¾	¾	1	8½	7	8	⅝	11/16	¾	⅞	3½
4	⅞	1⅛	1⅜	¾	⅞	1⅛	9	7½	8	⅝	11/16	¾	⅞	4
5	⅞	1¼	1½	⅞	1	1¼	11	9¼	8	¾	⅞	⅞	1	5
6	1	1¼	1½	⅞	1	1¼	12	10¼	12	¾	⅞	⅞	1	6
7	1	1⅜	1⅝	⅞	1⅛	1⅜	13¼	11½	12	¾	⅞	⅞	1	7
8	1⅛	1⅜	1⅝	1	1⅛	1⅜	14½	12¾	12	¾	⅞	⅞	1	8
9	1¼	1½	1¾	1	1¼	1½	16	14	12	⅞	1	1	1⅛	9
10	1⅛	1½	1⅞	1	1¼	1⅝	17	15	12	⅞	1	1	1⅛	10
12	1¼	1⅝	2	1⅛	1⅜	1¾	19¼	17¼	16	⅞	1	1	1⅛	12
14	1⅜	1¾	2⅛	1¼	1½	1⅞	21¾	19½	16	1	1⅛	1⅛	1¼	14
15	1⅜	1⅞	2⅛	1¼	1⅝	1⅞	22¾	20½	16	1	1⅛	1⅛	1¼	15
16	1⅜	1⅞	2¼	1¼	1⅝	2	24	21¾	20	1	1⅛	1⅛	1¼	16
18	1½	2	2⅜	1⅜	1¾	2⅛	26½	24	20	1⅛	1¼	1¼	1⅜	18
20	1⅝	2⅛	2½	1½	1⅞	2¼	29	26½	24	1⅛	1¼	1¼	1⅜	20
21	1⅝	2¼	2⅝	1½	2	2⅜	30	27½	24	1⅛	1¼	1¼	1⅜	21
24	1¾	2⅝	2¾	1⅝	2⅛	2½	33½	30¾	24	1¼	1⅜	1⅜	1¼	24

FILLING HOLES IN CAST IRON.

Melt together 9 parts lead.
,, ,, 2 ,, antimony.
,, ,, 1 part bismuth.
Warm the hole before filling.

RUST CEMENT.

Slow Setting.	Quick Setting.
200 parts iron borings.	80 parts iron borings.
2 ,, powdered sal-ammoniac.	1 part powdered sal-ammoniac
1 part flour sulphur.	2 parts flour sulphur.

SOLDERING FLUXES.

Iron and steel	use chloride of zinc, sal-ammoniac or bora
Copper and brass	,, chloride of zinc, resin or sal-ammonia
Zinc (new)	,, chloride of zinc.
,, (old)	,, hydrochloric acid.
Lead (with fine solder)	,, tallow and resin.
,, ,, coarse ,,	,, tallow.
Tin and pewter	,, resin and sweet oil.
Tinned iron	,, resin or chloride of zinc.

TEMPERATURE.

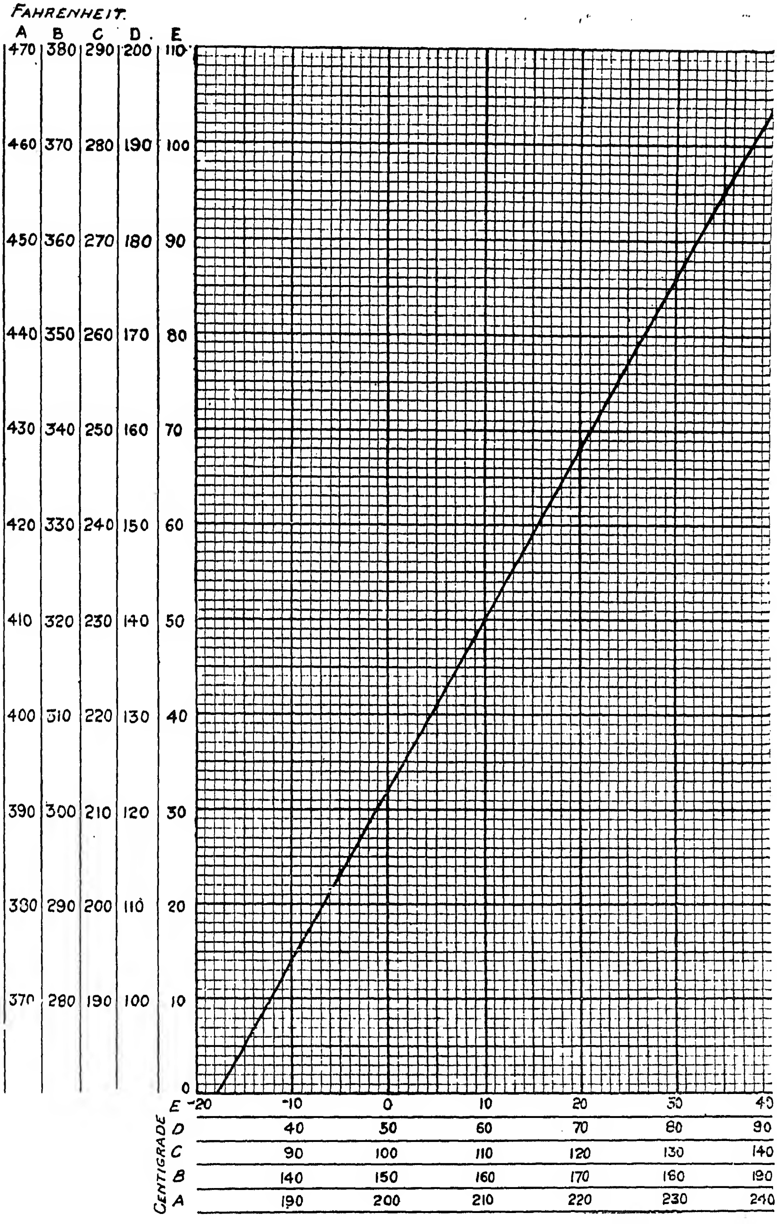
Conversion of Degrees Centigrade into Degrees Fahrenhei and vice versâ.

The accompanying chart gives a ready means of reading c equivalent values on either scale. It must be remembered th figures in any column on one scale must be read against the figur in the correspondingly lettered column on the other scale. Thu $-10°$ C. $= 14°$ F., and $338°$ F. $= 170°$ C. The chart may be extend to any extent by the addition of columns of degrees in the sar sequences. It will be seen that

1° C. contains 1·8° F., and 1° F. contains 0·56° C.

The corresponding values of any number of degrees may be foun by the use of one of the following formulæ :—

$$C.° = \frac{5}{9}(F.° - 32°). \quad F.° = \frac{9}{5}C.° + 32°.$$


FAHRENHEIT
A B C D E
470 380 290 200 110
460 370 280 190 100
450 360 270 180 90
440 350 260 170 80
430 340 250 160 70
420 330 240 150 60
410 320 230 140 50
400 310 220 130 40
390 300 210 120 30
330 290 200 110 20
370 280 190 100 10
0
E -20 -10 0 10 20 30 40
D 40 50 60 70 80 90
C 90 100 110 120 130 140
B 140 150 160 170 160 190
A 190 200 210 220 230 240
CENTIGRADE

SOLDER.

Common . .	1 tin,	1 lead.	
Fine . . .	2 ,,	1 ,,	
Coarse . . .	1 ,,	2 ,,	
Hard plumber's .	2 ,,	1 ,,	
Soft ,, .	1 ,,	3 ,,	
Hard pewterer's .	3 ,,	4 ,,	2 bismuth.
Soft ,, .	2 ,,	1 ,,	1 ,,
Hard spelter. .	12 zinc,	16 copper.	
Soft ,, . .	1 ,,	1 ,,	
For fine brass work	8 ,,	8 ,,	1 silver.
For steel .	1 ,,	3 ,,	19 ,,
Hard silver solder .	1 copper,	4 silver.	
Soft ,, ,, .	1 brass,	2 silver.	
Gold solder . .	24 gold,	2 silver,	1 copper.

SPEED OF PULLEYS.

$$\text{Revolutions of driven} = \frac{\text{Diameter of driver} \times \text{Revolutions of driver}}{\text{Diameter of driven.}}$$

$$\text{Diameter of driven} = \frac{\text{Diameter of driver} \times \text{Revolutions of driver}}{\text{Revolutions of driven.}}$$

$$\text{Revolutions of driver} = \frac{\text{Diameter of driven} \times \text{Revolutions of driven}}{\text{Revolutions of driver.}}$$

$$\text{Diameter of driver} = \frac{\text{Diameter of driven} \times \text{Revolutions of driven}}{\text{Revolutions of driver.}}$$

The distance apart of bearings, centre to centre, are calculated from the formula

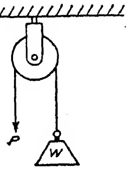
$$\text{Centres} = 5 \times \sqrt[3]{(\text{diameter of shaft in inches})^2}.$$

SAFE LOAD ON SHAFTING.

$$\text{Diameter in inches} = \sqrt[3]{\frac{65 \times \text{H.P. transmitted}}{\text{number of revs. per min.}}} \text{ (Molesworth).}$$

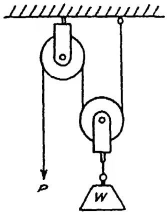
PULLEYS.

Single Fixed Pulley.



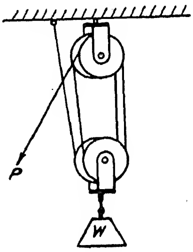
$$P = W.$$

Single Movable Pulley.



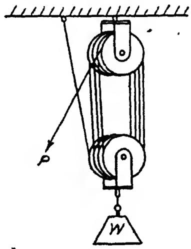
$$P = \frac{W}{2}.$$

Double Movable Pulley.



$$P = \frac{W}{4}.$$

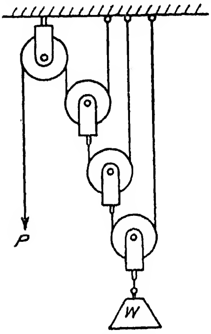
Multiple Movable Pulley.



x = number of movable pulleys.

$$P = \frac{W}{2x}.$$

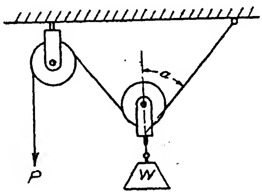
Compound Pulleys.



x = number of movable pulleys.

$$P = \frac{W}{2x}.$$

Oblique Fixed Pulleys.



$$P = \frac{W \sec a.}{2}$$

TABLE 55.—STRENGTHS OF MANILA AND HEMP ROPES (SAFE LOAD).

Circumference in Inches.	Manila.				Hemp.				Common Hemp.				Circumference in Inches.
	Pounds.	Tons	cwts.	lbs.	Pounds.	Tons	cwts.	lbs.	Pounds.	Tons	cwts.	lbs.	
1	100	0	0	100	80	0	0	80	55	0	0	55	1
2	400	0	3	64	320	0	2	96	220	0	1	108	2
3	900	0	8	4	700	0	6	28	500	0	4	52	3
4	1,600	0	14	32	1,300	0	11	68	900	0	8	4	4
5	2,500	1	2	36	2,000	0	17	96	1,350	0	12	6	5
6	3,500	1	11	28	2,900	1	5	100	1,950	0	17	46	6
7	4,900	2	3	84	3,900	1	14	92	2,700	1	4	12	7
8	6,400	2	17	16	5,100	2	5	60	3,500	1	11	28	8
9	8,000	3	11	48	6,400	2	17	16	4,400	1	19	32	9

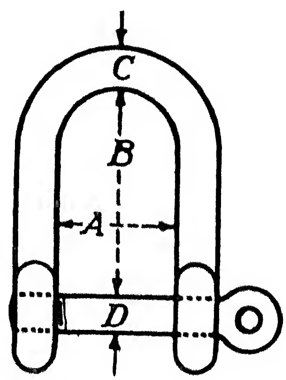


TABLE 56.—D. SHACKLES.

	A.	B.	C.	D.
in.	in.	in.	in.	in.
$\frac{3}{8}$	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$
$\frac{1}{2}$	1	$1\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$
$\frac{5}{8}$	$1\frac{5}{8}$	$2\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{4}$
$\frac{3}{4}$	$1\frac{5}{8}$	$3\frac{1}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
$\frac{7}{8}$	$1\frac{7}{8}$	$3\frac{1}{2}$	$\frac{7}{8}$	1
1	2	4	1	$1\frac{1}{8}$
$1\frac{1}{4}$	$2\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{8}$

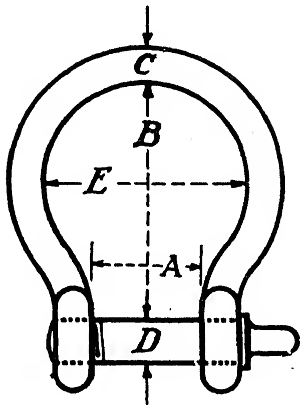


TABLE 57.—HARP SHACKLES.

	A.	B.	C.	D.	E.
in.	in.	in.	in.	in.	in.
$\frac{5}{16}$	$\frac{9}{16}$	$1\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	1
$\frac{3}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	1
$\frac{1}{2}$	$\frac{7}{8}$	$2\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{5}{8}$
$\frac{5}{8}$	$1\frac{3}{8}$	$2\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$1\frac{3}{4}$
$\frac{3}{4}$	$1\frac{3}{8}$	$3\frac{3}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	$2\frac{3}{8}$
$\frac{7}{8}$	2	4	$\frac{7}{8}$	1	$2\frac{7}{8}$
1	$2\frac{1}{4}$	5	1	$1\frac{1}{8}$	$3\frac{3}{8}$

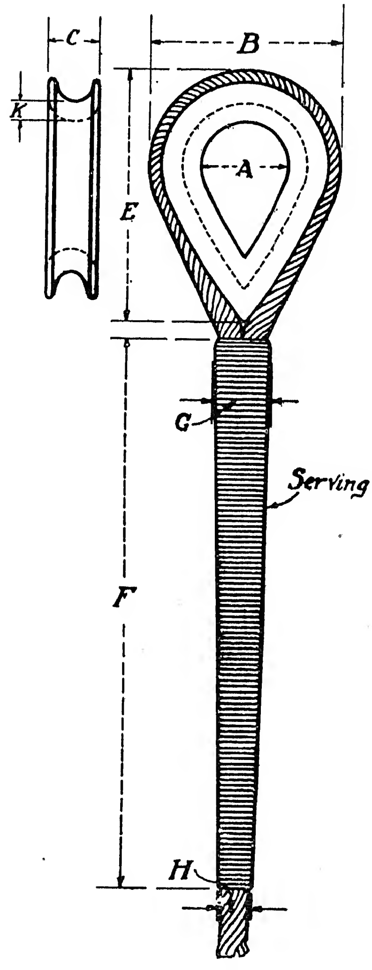

C
B
K
A
E
G
Serving
F
H

TABLE 58.—THIMBLE DIMENSIONS FOR WIRE ROPES.

Circum. of Rope.	Diameter of Rope.	A.	B.	C.	E.	F.	G.	H.	K.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
$1\frac{1}{4}$	$\frac{3}{8}$	1	$2\frac{1}{8}$	$\frac{5}{8}$	$2\frac{3}{4}$	9	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{3}{16}$
$1\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{8}$	$2\frac{1}{2}$	$\frac{3}{4}$	$3\frac{3}{8}$	11	1	$\frac{3}{4}$	$\frac{3}{16}$
$1\frac{3}{4}$	$\frac{9}{16}$	$1\frac{1}{4}$	$2\frac{7}{8}$	$\frac{7}{8}$	4	13	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{4}$
2	$\frac{5}{8}$	$1\frac{1}{2}$	$3\frac{1}{4}$	1	$4\frac{1}{2}$	15	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{1}{4}$
$2\frac{1}{4}$	$\frac{3}{4}$	$1\frac{3}{4}$	$3\frac{3}{4}$	$1\frac{1}{8}$	$5\frac{1}{8}$	17	$1\frac{3}{8}$	1	$\frac{1}{4}$
$2\frac{1}{2}$	$\frac{13}{16}$	2	$4\frac{3}{8}$	$1\frac{1}{4}$	$5\frac{5}{8}$	19	$1\frac{1}{2}$	1	$\frac{3}{8}$
$2\frac{3}{4}$	$\frac{7}{8}$	$2\frac{1}{4}$	$4\frac{3}{4}$	$1\frac{3}{8}$	$6\frac{1}{4}$	21	$1\frac{5}{8}$	$1\frac{1}{8}$	$\frac{3}{8}$
3	$\frac{15}{16}$	$2\frac{1}{2}$	$5\frac{3}{8}$	$1\frac{1}{2}$	$6\frac{7}{8}$	24	$1\frac{3}{4}$	$1\frac{1}{4}$	$\frac{1}{2}$
$3\frac{1}{4}$	$1\frac{1}{16}$	$2\frac{3}{4}$	$5\frac{7}{8}$	$1\frac{5}{8}$	$7\frac{1}{2}$	27	2	$1\frac{3}{8}$	$\frac{1}{2}$
$3\frac{1}{2}$	$1\frac{1}{8}$	3	$6\frac{1}{4}$	$1\frac{3}{4}$	8	30	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$
4	$1\frac{1}{4}$	$3\frac{1}{4}$	7	$1\frac{7}{8}$	9	33	$2\frac{1}{2}$	$1\frac{3}{4}$	$\frac{11}{16}$
$4\frac{1}{2}$	$1\frac{7}{16}$	$3\frac{1}{2}$	$7\frac{3}{4}$	2	10	36	$2\frac{3}{4}$	$1\frac{7}{8}$	$\frac{11}{16}$
5	$1\frac{9}{16}$	4	9	$2\frac{1}{4}$	11	39	$3\frac{1}{8}$	2	$\frac{7}{8}$
$5\frac{1}{2}$	$1\frac{3}{4}$	$4\frac{1}{2}$	$9\frac{3}{4}$	$2\frac{1}{2}$	12	42	$3\frac{1}{2}$	$2\frac{1}{4}$	$\frac{7}{8}$
6	$1\frac{15}{16}$	5	$11\frac{3}{8}$	3	13	46	$3\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$
$6\frac{1}{2}$	$2\frac{1}{8}$	$5\frac{1}{2}$	$12\frac{1}{4}$	$3\frac{1}{4}$	14	50	$4\frac{1}{8}$	$2\frac{3}{4}$	$1\frac{1}{4}$
7	$2\frac{1}{4}$	6	13	$3\frac{1}{2}$	16	54	$4\frac{3}{4}$	3	$1\frac{1}{4}$

From Bullivant & Co.'s Tables.

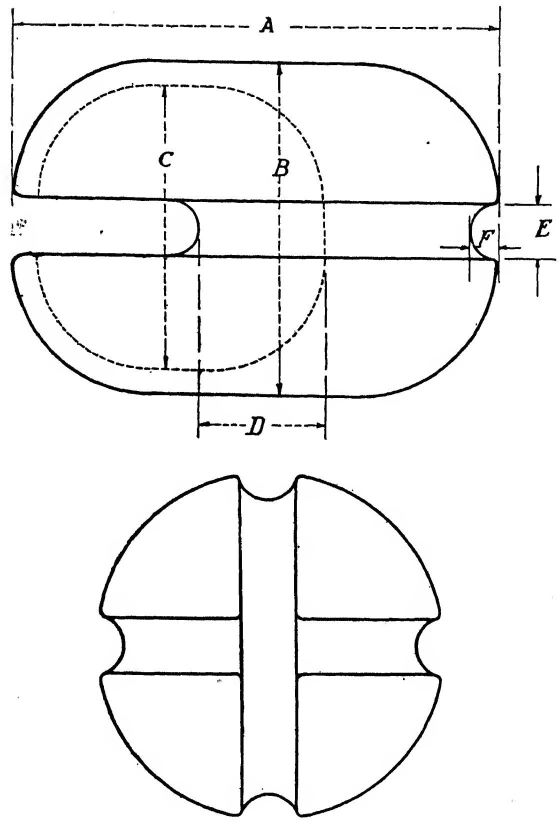


TABLE 59.—PORCELAIN STAY INSULATORS.

Size.	To take Flex Steel Wire.	A.	B.	C.	D.	E.	F.
		in.	in.	in.	in.	in.	in.
No. 1	1″ Circumference	$5\frac{1}{4}$	$3\frac{1}{2}$	—	$1\frac{1}{4}$	$\frac{1}{2}$	—
No. 2	$1\frac{1}{2}$″ ,,	6	$4\frac{1}{4}$	$3\frac{1}{2}$	$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{8}$
No. 3	$2\frac{1}{2}$″ ,,	$6\frac{5}{8}$	$4\frac{3}{4}$	$3\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{1}{16}$	$\frac{1}{2}$
No. 4	3″ ,,	$8\frac{5}{16}$	$5\frac{15}{16}$	$4\frac{3}{4}$	$2\frac{3}{8}$	$1\frac{3}{16}$	$\frac{19}{32}$

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